Grades 9–12
Life Science
Item Specifications

Updated October 2021

Missouri Department of Elementary & Secondary Education

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Introduction

In 2014 Missouri legislators passed House Bill 1490, mandating the development of the Missouri Learning Expectations. In April of 2016, these Missouri Learning Expectations were adopted by the State Board of Education. Groups of Missouri educators from across the state collaborated to create the documents necessary to support the implementation of these expectations.

One of the documents developed is the item specification document, which includes all Missouri grade level/course expectations arranged by domains/strands. It defines what could be measured on a variety of assessments. The document serves as the foundation of the assessment development process.

Although teachers may use this document to provide clarity to the expectations, these specifications are intended for summative, benchmark, and large-scale assessment purposes.

Components of the item specifications include:

Expectation Unwrapped breaks down a list of clearly delineated content and skills the students are expected to know and be able to do upon mastery of the Expectation.

Depth of Knowledge (DOK) Ceiling indicates the highest level of cognitive complexity that would typically be assessed on a large scale assessment. The DOK ceiling is not intended to limit the complexity one might reach in classroom instruction.

Item Format indicates the types of test questions used in large scale assessment. For each expectation, the item format specifies the type best suited for that particular expectation.

Content Limits/Assessment Boundaries are parameters that item writers should consider when developing a large scale assessment. For example, some expectations should not be assessed on a large scale assessment but are better suited for local assessment.

Sample stems are examples that address the specific elements of each expectation and address varying DOK levels. The sample stems provided in this document are in no way intended to limit the depth and breadth of possible item stems. The expectation should be assessed in a variety of ways.

Possible Evidence indicates observable methods in which a student can show understanding of the expectations.

Stimulus Materials defines types of stimulus materials that can be used in the item stems.

**Content has been adapted from The Wonder of Science - Assessments and the DC Science Assessment - Biology Practice Test.*

Grades 9-12 LIFE SCIENCE

<table>
<tr><th colspan="2">Engineering, Technology, and Applications of Science</th><th>9-12.ETS1.A.1</th></tr>
<tr><td>Core Idea</td><td colspan="2">Engineering Design</td></tr>
<tr><td>Component</td><td colspan="2">Defining and Delimiting Engineering Problems</td></tr>
<tr><td>MLS</td><td colspan="2">Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.</td></tr>
<tr><td colspan="2"><u>Expectation Unwrapped</u>

<u>SCIENCE AND ENGINEERING PRACTICES</u>
Asking Questions and Defining Problems
● Analyze complex real-world problems by specifying criteria and constraints for successful solutions.

<u>DISCIPLINARY CORE IDEAS</u>
Defining and Delimiting Engineering Problems
● Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
● Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

<u>CROSSCUTTING CONCEPTS</u>
Influence of Science, Engineering, and Technology on Society and the Natural World
● New technologies can have deep impacts on society and the environment, including some that were not anticipated.
● Analysis of costs and benefits is a critical aspect of decisions about technology.</td><td><u>DOK Ceiling</u>
3

<u>Item Format</u>
Selected Response
Constructed Response
Technology Enhanced</td></tr>
<tr><td colspan="2"><u>Content Limits/Assessment Boundaries</u>

● Tasks should require students to draw conclusions from graphs, data tables, or text to support their conclusions.
● Tasks should not require students to differentiate between credible and non-credible sources.</td><td><u>Stimulus Materials</u>

Graphic organizers, diagrams, graphs, data tables, drawings</td></tr>
</table>

Possible Evidence	

• Identify and analyze the problem to be solved.
  ○ Describe the challenge with a rationale for why it is a major global challenge.
  ○ Describe qualitatively and quantitatively, the extent and depth of the problem and its major consequences to society and/or the natural world on both global and local scales if it remains unsolved.
  ○ Document background research on the problem from two or more sources, including research journals.
• Define the boundaries in which this problem is embedded and the components of that system.
  ○ In their analysis, students identify the physical system in which the problem is embedded, including the major elements and relationships in the system and boundaries so as to clarify what is and is not part of the problem.
  ○ In their analysis, students describe societal needs and wants that are relative to the problem (e.g., for controlling CO_2 emissions, societal needs include the need for cheap energy).
• Define the criteria and limitations (constraints) of the possible solution.
  • Students specify qualitative and quantitative criteria and limitations (constraints) for acceptable solutions to the problem.	

Sample Stems **[Coming soon!]**	

Grades 9-12 LIFE SCIENCE

Engineering, Technology, and Application of Science		9-12.ETS1.A.2
Core Idea	**Engineering Design**	
Component	**Defining and Delimiting Engineering Problems**	
MLS	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.	
Expectation Unwrapped **SCIENCE AND ENGINEERING PRACTICES** **Constructing Explanations and Designing Solutions** ● Design a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations. **DISCIPLINARY CORE IDEAS** **Defining and Delimiting Engineering Problems** ● Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. ● Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. **Organizing the Design Solution** ● Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. **CROSSCUTTING CONCEPTS** **Stability and Change** ● Much of science deals with constructing explanations of how things change and how they remain stable.		**DOK Ceiling** 3 **Item Format** Selected Response Constructed Response Technology Enhanced
Content Limits/Assessment Boundaries ● Tasks may include complex real-world problems with more than one possible solution. All real-world problems used on the assessment should be provided to the student.		**Stimulus Materials** Graphic organizers, diagrams, graphs, data tables, drawings

Possible Evidence	
● Formulate a claim to potentially solve a complex real-world problem using a multistep solution based on scientific knowledge. ○ Students restate the original complex problem as a set of two or more subproblems (possibilities include in writing or as a diagram or flow chart). ○ For each of the subproblems, students propose at least one solution that is based on student-generated data and/or scientific information from other sources. ○ Students describe how solutions to the subproblems are interconnected to solve all or part of the larger problem. ● Describe criteria and limitations (constraints) of their solution, including quantification when appropriate. ○ Students describe the criteria and limitations (constraints) for the selected subproblem. ○ Students describe the rationale for the sequence of how subproblems are to be solved and which criteria should be given highest priority if trade-offs must be made.	
Sample Stems [Coming soon!]	

Grades 9-12 LIFE SCIENCE

<table>
<tr><th colspan="2">Engineering, Technology, and Application of Science</th><th>9-12.ETS1.B.1</th></tr>
<tr><td>Core Idea
Component
MLS</td><td colspan="2">Engineering Design
Developing Possible Solutions
Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.</td></tr>
<tr><td colspan="2" rowspan="2"><u>Expectation Unwrapped</u>

<u>SCIENCE AND ENGINEERING PRACTICES</u>
Constructing Explanations and Designing Solutions
● Evaluate a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.

<u>DISCIPLINARY CORE IDEAS</u>
Developing Possible Solutions
● When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

<u>CROSSCUTTING CONCEPTS</u>
Influence of Science, Engineering, and Technology on Society and the Natural World
● New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.</td><td><u>DOK Ceiling</u>
3</td></tr>
<tr><td><u>Item Format</u>
Selected Response
Constructed Response
Technology Enhanced</td></tr>
<tr><td colspan="2"><u>Content Limits/Assessment Boundaries</u>

● Tasks should require students to evaluate solutions based on at least two of the following: cost, safety, reliability, and aesthetics.
● Tasks should not require students to generate their own solutions.</td><td><u>Stimulus Materials</u>

Graphic organizers, diagrams, graphs, data tables, drawings</td></tr>
</table>

Possible Evidence	

• Students evaluate potential solutions.
  ○ Provide an evidence-based decision of which solution is optimum, based on prioritized criteria, analysis of the strengths and weaknesses of each solution, and barriers to be overcome.
• Students refine and/or optimize the design solution.
  ○ In their evaluation, students describe which parts of the complex real-world problem may remain even if the proposed solution is implemented.	

Sample Stems	
[Coming soon!]	

Engineering, Technology, and Application of Science		9-12.ETS1.B.2
Core Idea	Engineering Design	
Component	Developing Possible Solutions	
MLS	Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.	

Expectation Unwrapped	DOK Ceiling 3
SCIENCE AND ENGINEERING PRACTICES **Using Mathematics and Computational Thinking** ● Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. **DISCIPLINARY CORE IDEAS** **Developing Possible Solutions** ● Both physical models and computers can be used in various ways to aid in the engineering design process. ● Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical and in making a persuasive presentation to a client about how a given design will meet his or her needs. **CROSSCUTTING CONCEPTS** **Systems and System Models** ● Models (e.g. physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.	**Item Format** Selected Response Constructed Response Technology Enhanced

Content Limits/Assessment Boundaries	Stimulus Materials
● Tasks should include real-world problems that are relevant to students. Adequate background information is needed for any problem not potentially relevant to students. ● Tasks should not require students to generate their own complex real-world problem.	Graphic organizers, diagrams, graphs, data tables, drawings

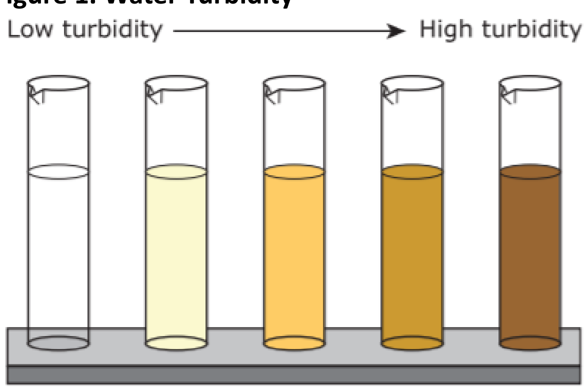
Possible Evidence

- Define what each part of the simulation represents.
    - Identify the complex real-world problem, with numerous criteria and limitations (constraints).
        - Identify the system that is being modeled by the computational simulation, including the boundaries and individual components of the systems.
        - Identify what variables can be changed by the user to evaluate the proposed solutions, trade-offs, or other decisions.
        - Identify the scientific principles and or relationships being used by the model.
- Students use the given computer simulation to model the proposed solutions by selecting logical and realistic inputs and using the model to simulate the effects of different solutions, trade-offs, or other decisions.
- Analyze how the criteria and limitations (constraints) impact the problem.
    - Students will be able to analyze the simulated results as compared to the expected results.
    - Students interpret the results of the simulation and predict the effects of the proposed solutions within and between systems relevant to the problem based on the interpretation.
    - Students identify the possible negative consequences of solutions that outweigh their benefits.
    - Students identify the simulation's limitations (constraints).

Sample Stems

A researcher investigating cattle in the Blue Mountains of Oregon observes the cattle drinking water from a local stream. The activity of the cattle muddies the clear water of the stream. After the cattle depart, the researcher finds that they have trampled and destroyed several fish eggs, which turn out to be from trout. and salmon species listed as "Threatened" under the Endangered Species Act. Salmon consume tiny animals, which in turn consume tiny producer organisms. The producers depend on sunlight passing into the water so that they can perform photosynthesis.

Figure 1. Water Turbidity



Grades 9-12 LIFE SCIENCE

1. A researcher plans to use a computer simulation to explore whether there are any procedures which would allow for cattle to drink from a stream while minimizing the impact on the eggs of threatened fish. In order to produce a simulation which accurately models this system, what steps should the researcher take? 2. A researcher wants to create a computer simulation of the freshwater ecosystems of the Blue Mountain area to try to find the most effective and least costly strategy to conserve threatened fish populations. Describe the difficulty in creating a computer simulation that is useful for this situation. 3. A researcher is working on a simulation to test the impact of a program of collecting and incubating threatened fish eggs and releasing them as young fish back into the environment. The simulation will be created to investigate whether the program successfully reduces the impact of cattle. It will also investigate the economic impacts of the program. **Part A:** To perform its functions, the simulation should be created to investigate whether the program successfully reduced the impact of cattle ranching by predicting a. whether cattle or fish are of greater economic value b. the lowest cost way to implement program procedures c. the cost per fish of implementing this program relative to others d. the proportion of fish produced under this program that are eaten by predators **e. the proportion of eggs hatched under this program that are expected to survive** **Part B:** To perform its functions, the simulation should be created to investigate whether the program is economical by predicting a. whether cattle or fish are of greater economic value b. the lowest cost way to implement program procedures **c. the cost per fish of implementing this program relative to others** d. the proportion of fish produced under this program that are eaten by predators e. the proportion of eggs hatched under this program that are expected to survive 5. The student uses a simulation to compare solutions to the problem of cattle damaging fish eggs. Order the steps in the procedure to produce a successful development and implementation cycle. - Refine the design and simulation. - Compare predicted and real design outcomes. - Simulate changes in conditions based on the design. - Implement the design in a test area. - Construct simulation of existing conditions in a representative area. - Collect initial data on real conditions.	

Grades 9-12 LIFE SCIENCE

<table>
<tr><th colspan="2">Life Sciences</th><th>9-12.LS1.A.1</th></tr>
<tr><td>Core Idea</td><td colspan="2">From Molecules to Organisms: Structure and Processes</td></tr>
<tr><td>Component</td><td colspan="2">Structure and Function</td></tr>
<tr><td>MLS</td><td colspan="2">Construct a model of how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.</td></tr>
<tr><td colspan="2"><u>Expectation Unwrapped</u>

[Clarification Statement: Genes are the regions in DNA that code for proteins. Basic transcription and translation explain the roles of DNA and RNA in coding the instructions for making polypeptides.]

<u>SCIENCE AND ENGINEERING PRACTICES</u>
Constructing Explanations and Designing Solutions
● Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

<u>DISCIPLINARY CORE IDEAS</u>
Structure and Function
● Systems of specialized cells within organisms help them perform the essential functions of life.
● All cells contain genetic information in the form of DNA molecules.
● Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.

<u>CROSSCUTTING CONCEPTS</u>
Structure and Function
● Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.</td><td><u>DOK Ceiling</u>
3

<u>Item Format</u>
Selected Response
Constructed Response
Technology Enhanced</td></tr>
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Content Limits/Assessment Boundaries

Tasks should not require students to distinguish between credible and non-credible sources.
Tasks requiring students to transcribe or translate a DNA sequence must also include a codon chart/wheel.
Tasks should not assess the functions of tRNA or rRNA.
Tasks should not require students to identify cell or tissue types, whole body systems, specific protein structures (folding) and functions, or the biochemistry of protein synthesis (i.e., enzymes).

</td>
<td rowspan="2">

Stimulus Materials

Graphic organizers, diagrams, graphs, data tables, drawings
</td></tr>
<tr><td>

Possible Evidence

Students construct an explanation that includes the idea that regions of DNA, called genes, determine the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
Students use a variety of valid and reliable sources for the evidence (e.g., theories, simulations, peer review, students' own investigations).
Identify and describe the evidence to construct their explanation, including that:

All cells contain DNA
DNA contains regions that are called genes
The sequence of genes contains instructions that code for proteins
Groups of specialized cells (tissues) use proteins to carry out functions that are essential to the organism

Students use reasoning to connect evidence, along with the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, to construct the explanation. Students describe the following chain of reasoning in their explanation:

Because all cells contain DNA, all cells contain genes that can code for the formation of proteins.
Body tissues are systems of specialized cells with similar structures and functions, each of whose functions are mainly carried out by the proteins they produce.
Proper function of many proteins is necessary for the proper functioning of the cells.
Gene sequence affects protein function, which in turn affects the function of body tissues.

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</table>

Sample Item Stems

Scientists Halt Flesh-eating Disease in Mice
A team that was led by scientists from Harvard Medical School in Boston, MA, made the surprising discovery while studying the disease-promoting tactics of Streptococcus pyogenes in mice with necrotizing fasciitis. Necrotizing fasciitis is a devastating condition that remains extremely challenging to treat and has a mortality rate that's unacceptably high," explains Isaac M. Chiu, assistant professor of microbiology and immunobiology at Harvard Medical School.

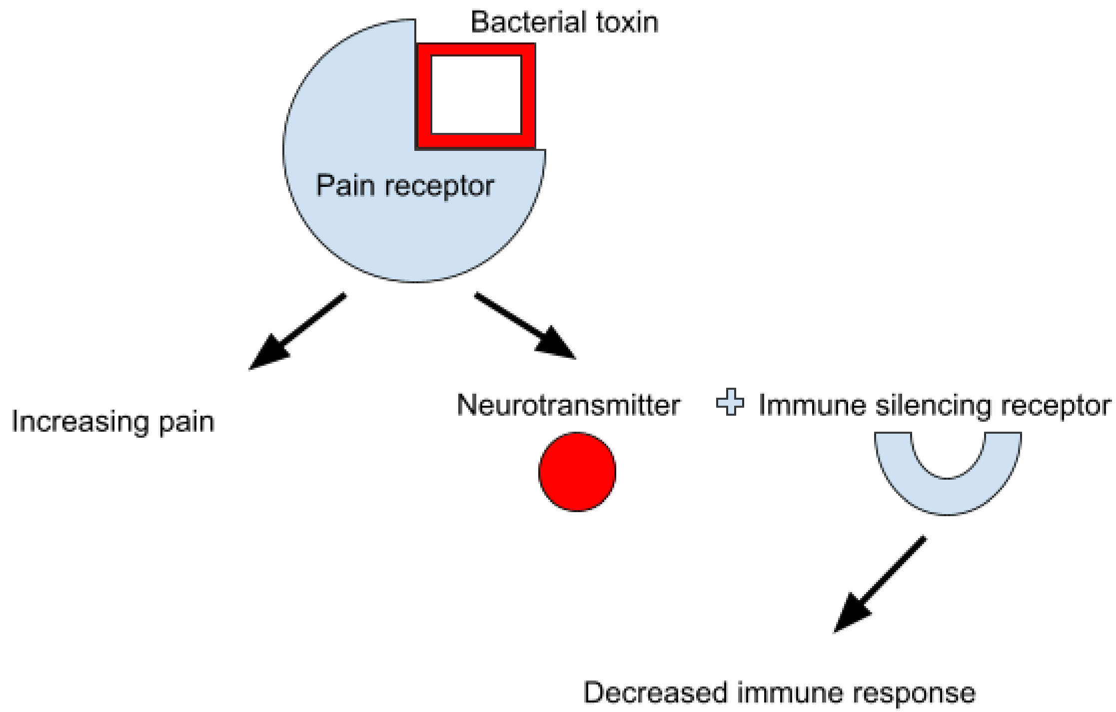
The flesh-eating disease is caused by serious bacterial infection of subcutaneous tissue, the tissue that lies just below the skin, and the fascia, the tissue that covers the organs that lie inside the body. The disease is very rare; each year, it affects approximately 200,000 people worldwide, which includes around 1,200 individuals in the United States. The infection — which can be caused by several types of bacteria — is not easy to diagnose, and it can develop suddenly and spread rapidly. If not treated promptly, it can result in "multiple organ failure and death," which occurs in around 30 percent of cases.

Following an injury, the nervous system sends one signal to the brain and another to the immune system. The first signal triggers pain sensations, and the second tells the immune system to hold back. Scientists suggest that neurons, or nerve cells, have this ability to instruct the immune system to hold back in order to prevent "over-deployment" of immune cells that might cause "collateral" damage to healthy tissue.

Prof. Chiu became interested in how this nervous system and immune system interaction might work in flesh-eating disease when he discovered that affected patients often experienced an excessive level of pain that occurred before symptoms developed. Could it be that the bacterium was somehow exploiting this natural dual response to injury to repress the immune system for its own advantage?

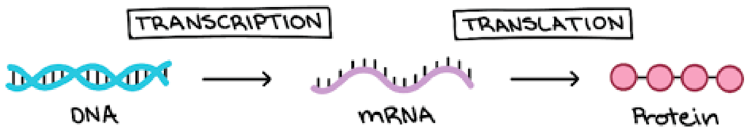
The results of this study suggests that the bacteria secretes a toxin that triggers neurons to send a pin signal to the brain. It then triggers another signal which causes a secretion of a neurotransmitter which suppresses the immune system and disrupts homeostasis.

Immune Silencing Pathway	



A microbiologist in the Washington University Lab is studying a recent outbreak of Flesh Eating Bacteria Necrotizing fasciitis in St. Louis. They claim that the link between pain and the immune system may be key in treating the bacteria. The microbiologist wants to test the effects of pain medication on the reduction of tissue damage from the bacteria.

1. State the claim the microbiologist is investigating.
2. **Part A:** Describe the essential role of an antibody.
   Part B: Using the information you provided in Part A and additional understandings, describe how a healthy human immune system would typically respond to an invading bacteria in order to maintain homeostasis.



-source: Khanacademy.org

3. Use the model above to explain the role of genes in the production of antibodies.

Design an experiment to test the claim that taking pain medications would allow the immune system to respond to the bacteria to restore homeostasis.

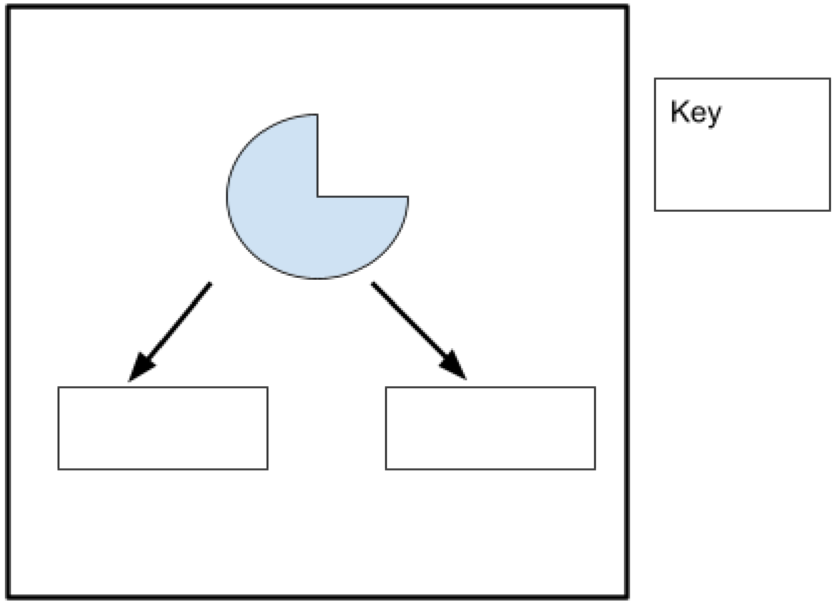
4. **Part A:** Explain how the control group would be treated differently than the experimental group.

   Part B: Identify the data that would be collected.

   Part C: Describe the results that would support your claim.

   Part D: Design the pain medication molecule that can be used on this pain receptor.

   Part E: Draw a model of what the pain receptor and the pain medication would look like after the person was given the pain medication.



Part F: Describe the effect on the pathways function if the pain medication in part D binds successfully with the pain receptor and changes its structure.

Life Sciences		9-12.LS1.A.2
Core Idea **Component** **MLS**	**From Molecules to Organisms: Structure and Processes** **Structure and Function** Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.	
Expectation Unwrapped		**DOK Ceiling** 3
[Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to stimuli. Similar cells work together to form tissues. Tissues work together to form organs. Organs work together to form organ systems. Organ systems interact to form an organism.] **SCIENCE AND ENGINEERING PRACTICES** **Developing and Using Models** ● Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. **DISCIPLINARY CORE IDEAS** **Structure and Function** ● Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. **CROSSCUTTING CONCEPTS** **System and System Models** ● Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. Refer to Engineering, Technology, and Application of Science ETS1.B.2		**Item Format** Selected Response Constructed Response Technology Enhanced
Content Limits/Assessment Boundaries ● Tasks should not include interactions or functions at the molecular or chemical reaction level. Any descriptions of relationships should be at the systems level. ● Tasks should not include the individual structure and function of parts of the systems (e.g., arteries, xylem).		**Stimulus Materials** Graphic organizers, diagrams, graphs, data tables, drawings

Possible Evidence

- Students develop a model in which they identify and describe the relevant parts (e.g., organ system, organs, and their component tissues) and processes (e.g., transport of fluids, motion) of body systems in multicellular organisms.
- Students describe the relationships between components.
    - In the model, students describe the relationships between components, including
        - the functions of at least two major body systems in terms of contributions to overall function of an organism,
        - ways the functions of two different systems affect one another, and
        - a system's function and how that relates both to the system's parts and to the overall function of the organism.
- Students use the model to illustrate how the interaction between systems provides specific functions in multicellular organisms.
- Students make a distinction between the accuracy of the model and actual body systems and functions it represents.

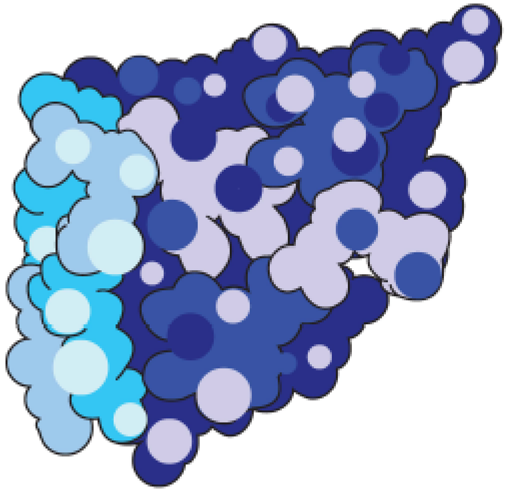
Sample Item Stems

A researcher is studying ocean pout (Zoarces americanus), an eel-like fish found in the cold waters of the northwest Atlantic Ocean.

Figure 1. Ocean Pout

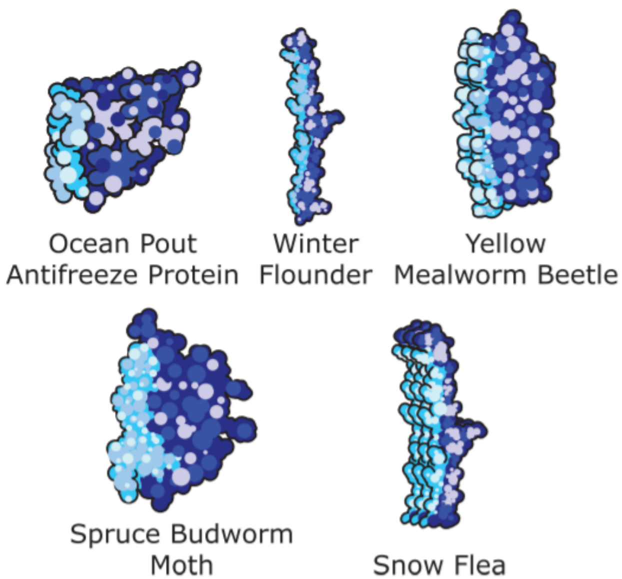
The researcher observes ocean pout surviving below the freezing temperature of water. Since the formation of ice crystals in cells destroys cell membranes, the researcher becomes interested in finding out how the ocean pout can survive such low temperatures. Follow-up work in the lab reveals that the ocean pout manufactures an "antifreeze" protein which reduces the freezing temperature of its blood and other body fluids.

Figure 2. Ocean Pout Antifreeze Protein



The active site of the protein works by attaching to ice crystals as they form and preventing them from expanding. Testing identifies the protein as AFP (type III antifreeze protein). It is similar in structure and function to antifreeze proteins found in other organisms.

Figure 3. Antifreeze Proteins of Several Organisms



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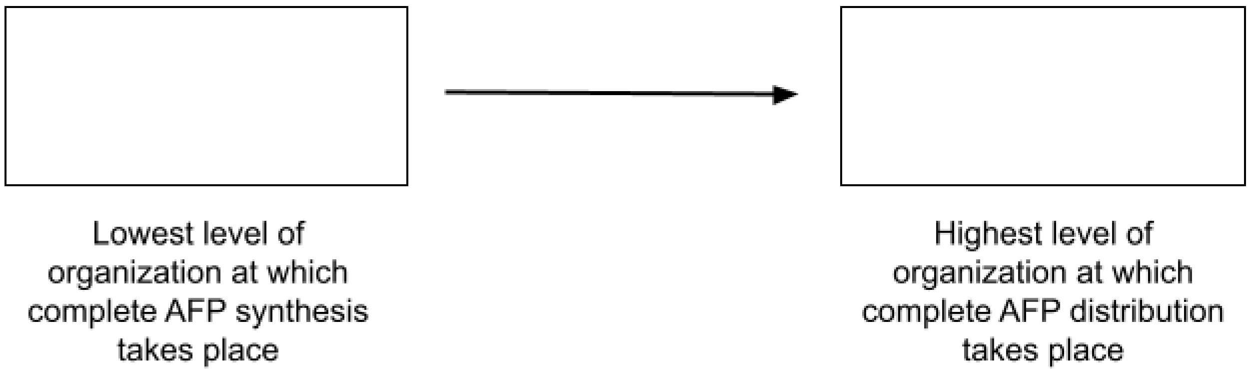
Messenger RNA coding for AFP is found at high concentrations in most tissues in the ocean pout, especially those of the liver, gills, and stomach. The manufactured protein then circulates inside and between cells, protecting the ocean pout as needed. This contrasts with similar fish, in which the antifreeze proteins are only manufactured in the liver.
AFP is coded for by the gene OPSa. Sequencing of AFP reveals the following amino acid sequence at one location in the protein:

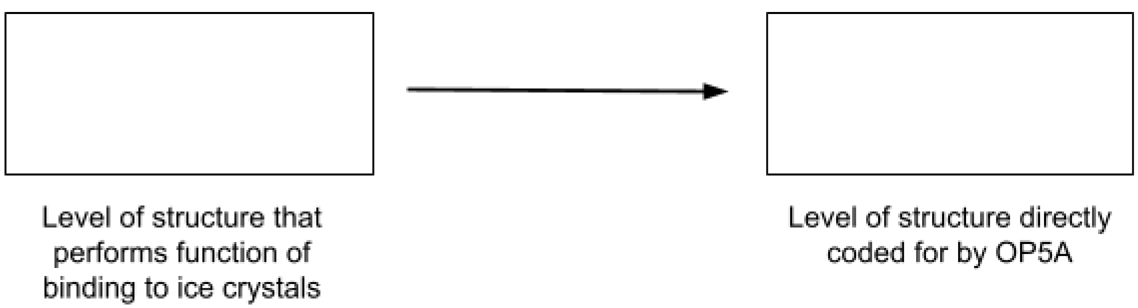
lysine-lysine-arginine-serine-glutamate

1. A student is developing a diagram model of AFP synthesis in ocean pout in terms of the ocean pout's level of organization. Write the correct answer in each box to complete the student's model.



2. A student is creating a presentation on the levels of structure in the AFP protein. The presentation includes the diagram below. Write the correct answer in each box to relate structure to function in AFP.

   Word bank: amino acid sequence, active site, nucleic acid sequence, entire protein, individual atoms



Grades 9-12 LIFE SCIENCE

Life Sciences		9-12.LS1.A.3
Core Idea Component MLS	**From Molecules to Organisms: Structure and Processes** **Structure and Function** Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.	

Expectation Unwrapped

[Clarification Statement: Examples of investigations could include heart rate response to exercise, stomata response to moisture and temperature, or root development in response to water levels.]

SCIENCE AND ENGINEERING PRACTICES

Planning and Carrying Out Investigations

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence and in the design
  - decide on types, quantity, and accuracy of data needed to produce reliable measurements;
  - consider limitations on the precision of the data (e.g., number of trials, cost, risk, time);
  - refine the design accordingly.

Scientific Investigations Use a Variety of Methods

- Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, reliability, of results, and honest and ethical reporting of findings.

DISCIPLINARY CORE IDEAS

Structure and Function

- Multicellular organisms have a hierarchical structural organization in which any one system is made up of numerous parts and is itself a component of the next level.

CROSSCUTTING CONCEPTS

Stability and Change

- Feedback (negative or positive) can stabilize or destabilize a system.

DOK Ceiling

3

Item Format

Selected Response
Constructed Response
Technology Enhanced

<table>
<tr><th><u>Content Limits/Assessment Boundaries</u></th><th><u>Stimulus Materials</u></th></tr>
<tr><td>

Tasks should focus on students recognizing and understanding the feedback mechanisms present in internal environments.
Tasks should provide students with enough background knowledge—students are not expected to know the physiological processes.
Tasks should not assess the cellular processes involved in the feedback mechanisms (e.g., cell receptors opening channels).
Tasks can address all aspects of experimental design and scientific method.

</td><td rowspan="3">Graphic organizers, diagrams, graphs, data tables, drawings</td></tr>
<tr><th><u>Possible Evidence</u></th></tr>
<tr><td>

Make a claim identifying the phenomenon under investigation.

Students describe the phenomenon under investigation, which includes the following idea: that feedback mechanisms maintain homeostasis.
Students develop an investigation plan and describe the data that will be collected and the evidence to be derived from the data, including

changes within a chosen range in the external environment of a living system and
responses of a living system that would stabilize and maintain the system’s internal conditions (homeostasis), even though external conditions change, thus establishing the positive or negative feedback mechanism.

Students describe why the data will provide information relevant to the purpose of the investigation.

Planning the investigation.

In the investigation plan, students describe the following:

How the change in the external environment is to be measured or identified
How the response of the living system will be measured or identified
How the stabilization or destabilization of the systems internal conditions will be measured or determined
The experimental procedure, the minimum number of different systems (and the factors that affect them) that would allow generalization of results, the evidence derived from the data, and identification of limitations on the precision of data to include types and amounts
Whether the investigation will be conducted individually or collaboratively.

Students collect and record changes in the external environment and organism responses as a function of time.
Students evaluate their investigation, including

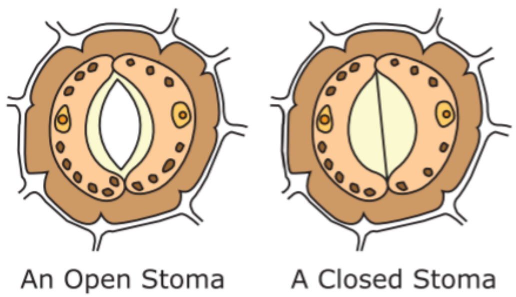
assessment of the accuracy and precision of the data, as well as limitations (e.g., cost risk, time) of the investigation and suggestions for refinement, and
assessment of the ability of the data to provide the evidence required.

</td></tr>
</table>

Sample Item Stems

A student uses a light microscope to examine the leaf of a tomato plant. She observes that tiny openings in the plant leaves open and close under different light conditions. These openings are called stomata (singular: stoma).

Figure 1. Stomata



The student decides to design an experiment exploring how stomata open and close in a tomato plant in response to stimuli. The results will allow the student to model the relationship of stomata to homeostasis in the plant overall. The student exposed the plants to different amounts of light and humidity for a period of 30 minutes and then made observations. The students' summary of the experimental results are shown in the table.

Table 1. Experimental Results

Experimental Condition		Stomata State
Brightness	**Humidity**	**Results**
Very bright	Humid	Open
Very bright	Dry	Closed
Ordinary brightness	Very humid	Open
Ordinary brightness	Very dry	Closed
No light - dark	Humid	Closed
No light - dark	Dry	Closed

Figure 2. Levels of Organization in the Student's Model

Molecules → Organelles → Cells → Tissues → Organs → Organ Systems → Organism

1. In a plant, when the turgor pressure is low, the stomata close and the leaves wilt. When the turgor pressure is high, the stomata open and the leaves are firm. Based on the data in Table 1, under which conditions would the leaf stay firm? 2. The student is conceptually modeling stomata in terms of their function. Complete the sentence below by selecting one answer choice for each blank (set of parentheses). A stoma operates on the flow of (carbohydrates/change/light/water vapor) into and out of the leaf by acting as a (consumer of the matter or energy flowing through it/producer of the matter or energy flowing through it, a one-way valve, a two-way gate).	

Grades 9-12 LIFE SCIENCE

Life Sciences		9-12.LS1.B.1
Core Idea	**From Molecules to Organisms: Structure and Processes**	
Component	**Growth and Development of Organisms**	
MLS	Develop and use models to communicate the role of mitosis, cellular division, and differentiation in producing and maintaining complex organisms.	

Expectation Unwrapped	**DOK Ceiling**
	3
[Clarification Statement: Major events of the cell cycle include cell growth, DNA replication, preparation for division, separation of chromosomes, and separation of cell contents.] **SCIENCE AND ENGINEERING PRACTICES** **Developing and Using Models** ● Use a model based on evidence to illustrate the relationships between systems or between components of a system. **DISCIPLINARY CORE IDEAS** **Growth and Development of Organisms** ● In multicellular organisms, individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. ● The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. ● Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. **CROSSCUTTING CONCEPTS** **Systems and System Models** ● Models (e.g., physical, mathematical, computer) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.	**Item Format** Selected Response Constructed Response Technology Enhanced

Content Limits/Assessment Boundaries	**Stimulus Materials**
● Tasks should not include meiosis, specific gene control mechanisms, rote memorization of the steps of mitosis. ● Tasks should focus on the nucleus, chromosomes, cell membrane, cell wall, nuclear membrane, and cytoplasm. All other cell parts (e.g., spindle fibers, mitochondria, centrioles) should not be used.	Graphic organizers, diagrams, graphs, data tables, drawings

Possible Evidence

- From a student-generated or given model, students identify and describe the components of the model relevant for illustrating the roles of mitosis, cellular division, and differentiation in producing and maintaining complex organisms.
  - Genetic material containing two variants of each chromosome pair, one from each parent
  - Parent and daughter cells (i.e., inputs and outputs of mitosis)
  - A multicellular organism as a collection of differentiated cells
- Students identify and describe the relationships between components of the given model.
  - Daughter cells receive identical genetic information from a parent cell or a fertilized egg.
  - Mitotic cell division produces two genetically identical daughter cells from one parent cell.
  - Differences between different cell types within a multicellular organism are due to gene expression—not different genetic material within that organism.
- Students use the given model to illustrate that mitotic cell division results in more cells that
  - allow growth of the organism,
  - can then differentiate to create different cell types, and
  - can replace dead cells to maintain a complex organism.
- Students make a distinction between the accuracy of the model and the actual process of cellular division.

Sample Stems

A child was injured in an accident which caused both kidneys to fail. A matching organ donor was unavailable. As the child's doctor you must replace the damaged organs. Fortunately, his parents opted to bank their child's cord blood shortly after birth because of the family's medical history. The umbilical cord, or lifeline between the mother and child in utero, is often discarded as medical waste; however, the blood within the umbilical cord and the surrounding tissue are packed with many types of valuable stem cells. Stem cells are unique cells with qualities that can help repair and heal the body. Figure 1 shows how cells begin as stem cells and can become other types of cells within the body.

Figure 1. Differentiation of Cells

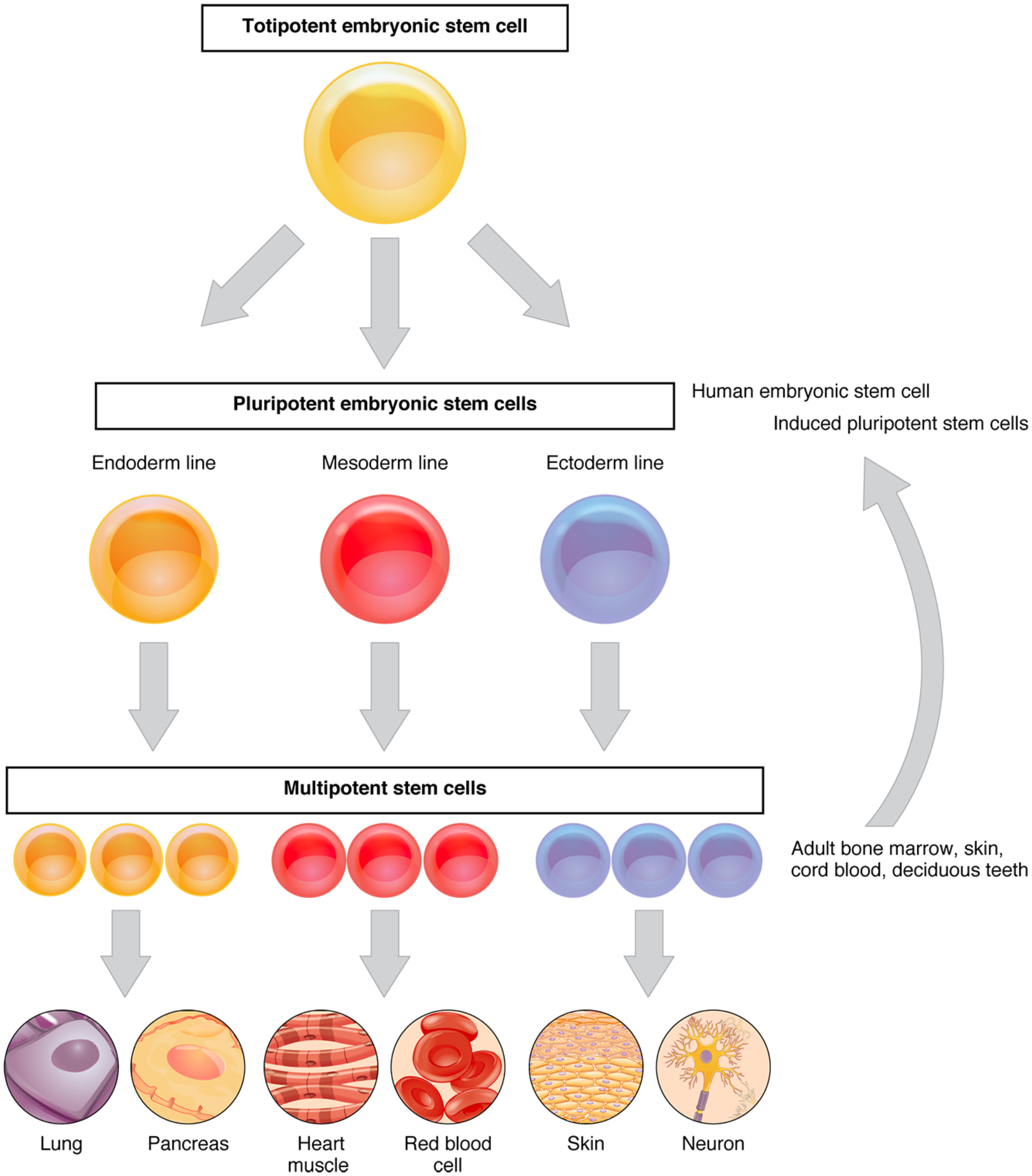


Figure 2. Kidney Structure

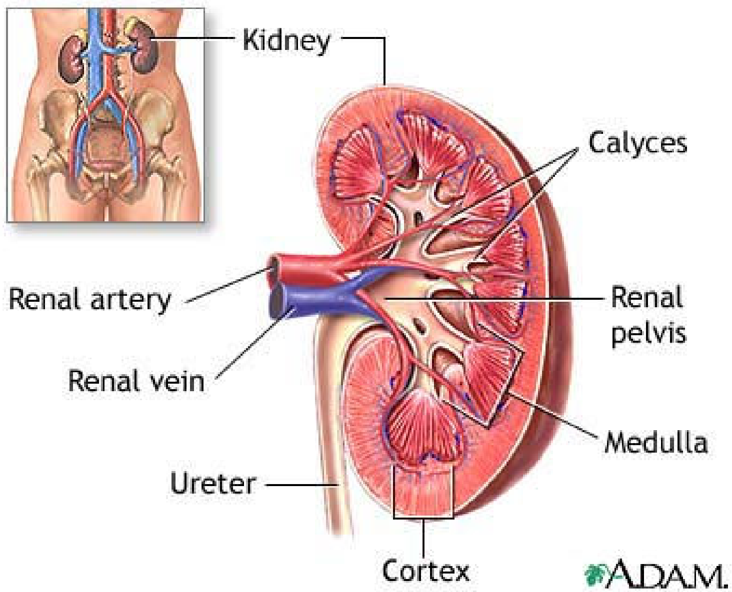
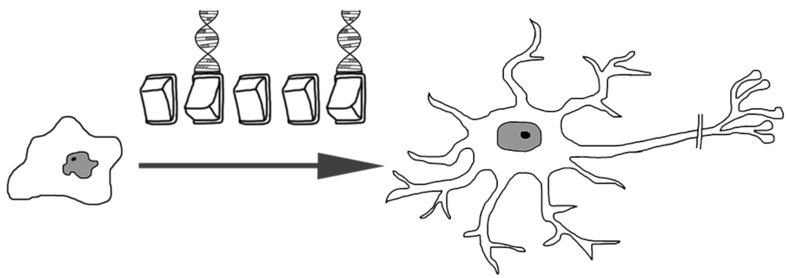


Figure 3. Genetic Switches



Use Figures 1-3 to answer the following questions:

1. Compare the genes of an individual's stem cells with their kidney cells.
2. Using the models, what genetic changes needed to be made in stem cells so that they could develop into kidney cells?
3. Once a small number of kidney cells are formed, identify and describe the cellular process that needs to occur to form an entire kidney.
4. Based on Figure 3, would the creation of one type of kidney cell be sufficient in forming a functioning kidney? Explain your reasoning.

Grades 9-12 LIFE SCIENCE

<table>
<tr><th colspan="2">Life Sciences</th><th>9-12.LS1.C.1</th></tr>
<tr><td>Core Idea</td><td colspan="2">From Molecules to Organisms: Structure and Processes</td></tr>
<tr><td>Component</td><td colspan="2">Organization for Matter and Energy Flow in Organisms</td></tr>
<tr><td>MLS</td><td colspan="2">Use a model to demonstrate how photosynthesis transforms light energy into stored chemical energy.</td></tr>
<tr><td colspan="2"><u>Expectation Unwrapped</u>

[Clarification Statement: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.]

<u>SCIENCE AND ENGINEERING PRACTICES</u>
Developing and Using Models
● Use a model based on evidence to illustrate the relationships between systems or between components of a system.

<u>DISCIPLINARY CORE IDEAS</u>
Organization for Matter and Energy Flow in Organisms
● The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.

<u>CROSSCUTTING CONCEPTS</u>
Energy and Matter
● Changes of energy and matter in a system can be described in terms of energy, matter flows into, out of, and within that system.</td><td><u>DOK Ceiling</u>
3

<u>Item Format</u>
Selected Response
Constructed Response
Technology Enhanced</td></tr>
<tr><td colspan="2"><u>Content Limits/Assessment Boundaries</u>

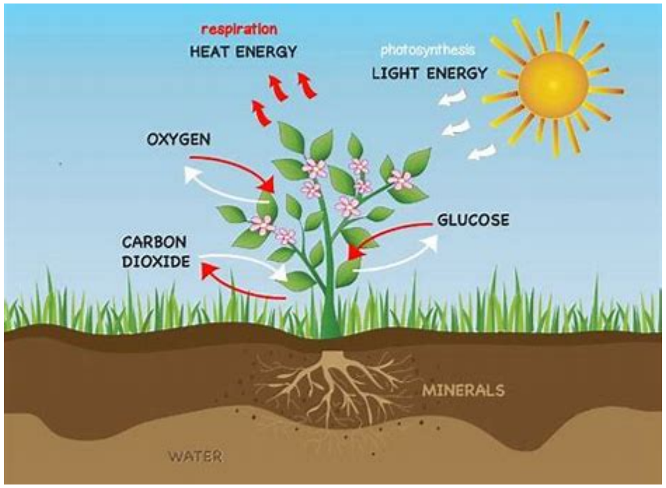
● Tasks should not require students to memorize or balance chemical equations.
● Tasks should not include specific biochemical processes (e.g., light independent and dependent reactions).</td><td><u>Stimulus Materials</u>

Graphic organizers, diagrams, graphs, data tables, drawings</td></tr>
</table>

Possible Evidence	
● From a given model, students identify and describe the components of the model relevant for illustrating that photosynthesis transforms light energy into stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen, including ○ energy in the form of light. ○ Energy is stored in the chemical bonds. ○ matter in the form of carbon dioxide, water, sugar, and oxygen. ● Students identify the following relationship between components of the given model: Sugar and oxygen are produced from carbon dioxide and water through the process of photosynthesis. ● Students a given model to illustrate ○ the transfer of matter and flow of energy between the organism and its environment during photosynthesis. ○ photosynthesis resulting in the storage of energy in the difference between the energies of the chemical bonds of the inputs (carbon dioxide and water) and outputs (sugar and oxygen).	
Sample Stems	
You bring home an air plant. Your mom does not think it can survive. You argue that the air plant is no different than any other plant. **Figure 1. Air Plant**  *Image from Bloom Coutoure; https://bloomcoutureboston.com/boston-bloom-couture-floral-studio/air-plants-doubled-in-clear-glass-containers.html*	

You bring this conversation to your Biology teacher to explore as a class. First, you consult textbooks in the classroom to find Figure 2 explaining photosynthesis. The first thing that draws the class's attention is the fact that soil is present in the model, but is not present with air plants. The teacher then asks students to consider places where the sun's energy might be used without soil. From this discussion, together the class creates a model to explain their thinking about solar panels, Figure 3.

Figure 2. Photosynthesis Model from Textbook



https://i.pinimg.com/originals/25/ce/31/25ce318d96b4b07de83bd66784e3eaf3.jpg

Figure 3. Class Generated Photosynthesis Model

As students in the class continue to understand this idea, they try to understand what cycles through the air plant. They remember that inorder to be living, the organism must grow and develop, so they plan and conduct an investigation monitoring the growth of the air plant over the remaining eight months of the school year. Table 1 shows the data they collected.

Table 1. Air Plant Growth Data

Months	Mass (grams)
1	1.5
2	10
3	17
4	24.5
5	32
6	37.4
7	42
8	60.2

1. Using Figure 2 and 3, define the inputs and outputs of the system.
2. **Part A:** Using the class generated model (Figure 3), provide evidence for what happens to the inputs of the system when light energy is absorbed.
   Part B: Using your answer from Part A, generate a chemical equation to describe the process of photosynthesis.
3. Describe how light energy was needed for the reaction to occur in the case of air plants.
4. Based on the data in Table 1, explain how the plant can use photosynthesis to increase its mass.
5. Describe why the air plant was able to grow, compared to the traditional terrestrial plant.
6. Suppose the teacher moved the air plant to a dark closet for a couple days. Would the plant still be alive when you check on it? Describe why or why not.

Grades 9-12 LIFE SCIENCE

Life Sciences		9-12.LS1.C.2
Core Idea	**From Molecules to Organisms: Structure and Processes**	
Component	**Organization for Matter and Energy Flow in Organisms**	
MLS	Use a model to demonstrate that cellular respiration is a chemical process whereby the bonds of molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.	

Expectation Unwrapped

[Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.]

SCIENCE AND ENGINEERING PRACTICES
Developing and Using Models
- Use a model based on evidence to illustrate the relationships between systems or between components of a system.

DISCIPLINARY CORE IDEAS
Organization for Matter and Energy Flow in Organisms
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.
- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another.
- Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles.
- Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.

CROSSCUTTING CONCEPTS
Energy and Matter
- Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.

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3

Item Format
Selected Response
Constructed Response
Technology Enhanced

Content Limits/Assessment Boundaries

- Tasks should focus on the overall inputs and outputs of the process of cellular respiration
- Tasks should not require students to identify the steps or specific processes involved in cellular respiration (e.g., glycolysis, Kreb's Cycle).
- Tasks should not require students to memorize or balance chemical equations.

Stimulus Materials

Graphic organizers, diagrams, graphs, data tables, drawings

- Tasks should not include anaerobic cellular respiration.

Possible Evidence

- From a given model, students identify and describe the components of the model relevant for their demonstration of cellular respiration, including
    - matter in the form of food molecules, oxygen, and the products of their reaction (e.g., water and CO_2).
    - the breaking and formation of chemical bonds.
    - energy from the chemical reactions.
- From a given model, students describe the relationships between components, including the following:
    - Carbon dioxide and water are produced from sugar and oxygen by the process of cellular respiration.
    - The process of cellular respiration releases energy because the energy released when the bonds are formed in CO_2 and water is greater than the energy required to break the bonds of sugar and oxygen.
- Students use a given model to illustrate that:
    - the chemical reaction of oxygen and food molecules releases energy as the matter is rearranged, existing chemical bonds are broken, and new chemical bonds are formed, but matter and energy are neither created nor destroyed.
    - food molecules and oxygen transfer energy to the cell to sustain life's processes, including the maintenance of body temperature, despite ongoing energy transfer to the surrounding environment.

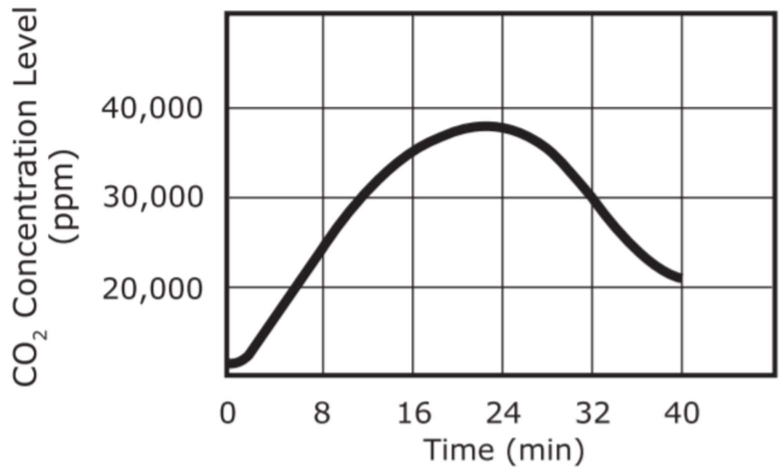
Sample Stems

A terrarium is a closed system that was made by adding gravel, sand, soil, plants, worms, insects, and snails to a glass bottle. A carbon dioxide sensor on a probe was sealed inside of the bottle as shown in Figure 1.

Figure 1. Carbon Dioxide Sensor on Probe in Terrarium

The mass of the plants remained constant during the experiment. The data that was collected is shown in Figure 2.

Figure 2. Carbon Dioxide Concentration Level



1. Write a statement using evidence from Figure 2 to best describe what is happening in the terrarium after 16 minutes have elapsed.
2. Different processes in the terrarium result in different changes to the carbon dioxide concentration. Match the process with its effect on the carbon dioxide concentration inside the terrarium. Write the correct answer in each box. Not all answers will be used.

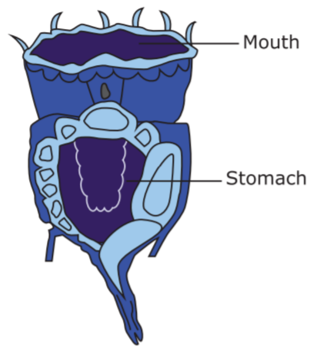
Word Bank					
plants respire	plants photosynthesize	insects respire	insects photosynthesize	snails respire	snails photosynthesize

Increases carbon dioxide	**Decreases carbon dioxide**

Life Sciences		9-12.LS1.C.3
Core Idea	**From Molecules to Organisms: Structure and Processes**	
Component	**Organization for Matter and Energy Flow in Organisms**	
MLS	Construct and revise an explanation based on evidence that organic macromolecules are primarily composed of six elements, where carbon, hydrogen, and oxygen atoms may combine with nitrogen, sulfur, and phosphorus to form large carbon-based molecules.	
Expectation Unwrapped [Clarification Statement: Large carbon-based molecules included are proteins, carbohydrates, nucleic acids, and lipids. Emphasis is on the inclusion of the element, not the structural organization of the macromolecule and on using evidence from models and simulations to support explanations.] **SCIENCE AND ENGINEERING PRACTICES** **Constructing Explanations and Designing Solutions** ● Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and on the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. **DISCIPLINARY CORE IDEAS** **Organization for Matter and Energy Flow in Organisms** ● The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used to form new cells. ● As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. **CROSSCUTTING CONCEPTS** **Energy and Matter** ● Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.		**DOK Ceiling** 3 **Item Format** Selected Response Constructed Response Technology Enhanced
Content Limits/Assessment Boundaries ● Tasks should include all necessary models. ● Tasks should not require students to identify macromolecules based on chemical structure. ● Tasks should not include the details of specific chemical reactions or bonding.		**Stimulus Materials** Graphic organizers, diagrams, graphs, data tables, drawings

Possible Evidence	
● Students make a claim explaining the phenomena (chemical structure of a macromolecule). ○ The relationship between the carbon, hydrogen, and oxygen atoms from sugar molecules formed in or ingested by an organism and those same atoms found in amino acids and other large carbon-based molecules ○ Larger carbon-based molecules and amino acids resulting from chemical reactions between sugar molecules (or their component atoms) and other atoms ● Students identify and describe the evidence to construct their explanation, including the following: ○ All organisms take in matter (allowing growth and maintenance) and rearrange the atoms in chemical reactions. ○ Cellular respiration involves chemical reactions between sugar molecules and other molecules in which energy is released that can be used to drive other chemical reactions. ○ Sugar molecules are composed of carbon, oxygen, and hydrogen atoms. ○ Amino acids and other complex carbon-based molecules are composed largely of carbon, oxygen, and hydrogen atoms. ○ Chemical reactions can create products that are more complex than the reactants. ○ Chemical reactions involve changes in the energies of the molecules involved in the reaction. ○ Students use a variety of valid and reliable sources for the evidence (e.g., theories, simulations, peer review, students' own investigations). ● Students use reasoning to connect the evidence, along with the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, to construct the explanation that atoms from sugar molecules may combine with other elements via chemical reactions to form other large carbon-based molecules. Students describe the following chain of reasoning for their explanation: ○ The atoms in sugar molecules can provide most of the atoms that comprise amino acids and other complex carbon-based molecules. ○ The energy released in respiration can be used to drive chemical reactions between sugars and other substances, and the products of those reactions can include amino acids and other complex carbon-based molecules. ○ The matter flows in cellular processes are the result of the rearrangement of primarily the atoms in sugar molecules because those are the molecules whose reactions release the energy needed for cell processes. ● Given new evidence or context, students revise or expand their explanation about the relationships between atoms in sugar molecules and atoms in large carbon-based molecules and justify their revision.	
Sample Stems On a field trip, a student collects a sample of lake water and examines it under a microscope. The student sees a microscopic animal with a clearly visible mouth and stomach. Her teacher identifies the organism as a type of zooplankton.	

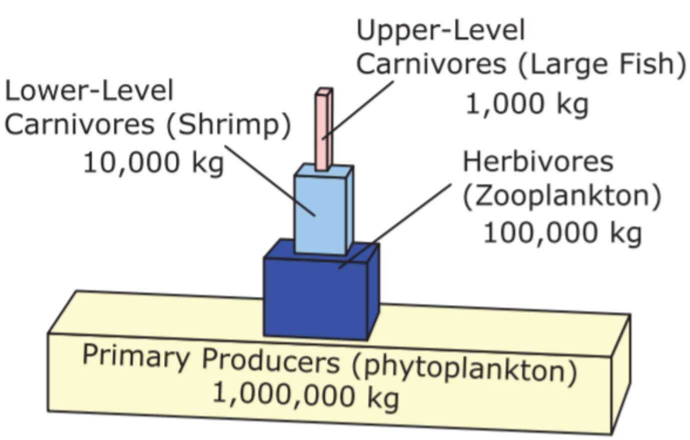
Figure 1. Zooplankton



The zooplankton takes water into its mouth, which it then filters, sending tiny particles of photosynthetic algae (phytoplankton) to its stomach for digestion. The student observes the feeding activity of the zooplankton, although the particles they are consuming are so small they remain invisible under the student's microscope.

The student also observes zooplankton of varying sizes. The student cannot measure absolute size, but observes individuals within a single species ranging from a smallest observed size to three times that size. Her teacher explains that in addition to natural size variation, zooplankton get larger as they mature. The student researches the ecological role of zooplankton and finds a simplified model of biomass at different trophic levels in ecosystems which includes zooplankton:

Figure 2. Aquatic Biomass Pyramid



Grades 9-12 LIFE SCIENCE

1. Given the information the student collected, provide an explanation for the observed changes in maturing zooplankton body size.
2. The student is working on an explanation for zooplankton size change in terms of ingested phytoplankton material. The student thinks that most of the matter needed for this growth could be derived from molecules formed directly during photosynthesis in phytoplankton. The student sorts elements by the following classifications. Place an X in the boxes to indicate yes for each element.

Description	**Carbon**	**Hydrogen**	**Nitrogen**	**Oxygen**
Obtained from sources other than photosynthesis				
Used to construct all protein molecules				

Grades 9-12 LIFE SCIENCE

<table>
<tr><th colspan="2">Life Sciences</th><th>9-12.LS2.A.1</th></tr>
<tr><td>Core Idea</td><td colspan="2">Ecosystems: Interactions, Energy, and Dynamics</td></tr>
<tr><td>Component</td><td colspan="2">Interdependent Relationships in Ecosystems</td></tr>
<tr><td>MLS</td><td colspan="2">Explain how various biotic and abiotic factors affect the carrying capacity and biodiversity of an ecosystem using mathematical and/or computational representations.</td></tr>
<tr><td colspan="2"><u>Expectation Unwrapped</u>

[Clarification Statement: Examples of biotic factors could include relationships among individuals (e.g., feeding relationships, symbioses, competition) and disease. Examples of abiotic factors could include climate and weather conditions, natural disasters, and availability of resources. Genetic diversity includes within a population and species within an ecosystem. Examples of mathematical comparisons could include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.]

<u>SCIENCE AND ENGINEERING PRACTICES</u>
Using Mathematics and Computational Thinking
● Use mathematical and/or computational representations of phenomena or design solutions to support explanations.

<u>DISCIPLINARY CORE IDEAS</u>
Interdependent Relationships in Ecosystems
● Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support.
● These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease.
● Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite.
● This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.

<u>CROSSCUTTING CONCEPTS</u>
Scale, Proportion, and Quantity
● The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.</td><td><u>DOK Ceiling</u>
3

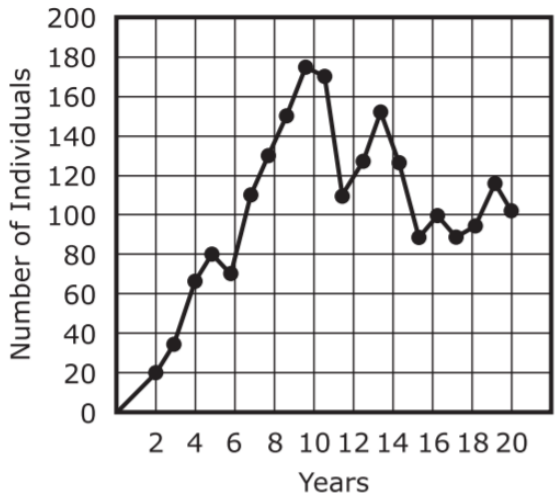
<u>Item Format</u>
Selected Response
Constructed Response
Technology Enhanced</td></tr>
<tr><td colspan="2"><u>Content Limits/Assessment Boundaries</u>

● Tasks should require students to create graphs based on given data tables. Students are not required to calculate the data necessary to complete a graph.</td><td><u>Stimulus Materials</u>

Graphic organizers, diagrams, graphs, data tables, drawings</td></tr>
</table>

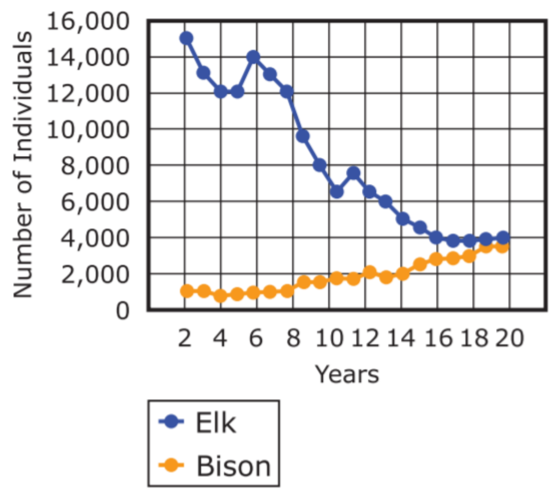
Possible Evidence	
● Students identify and describe the components in the given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) that are relevant to supporting given explanations of factors that affect carrying capacities of ecosystems at different scales. The components include o the population changes gathered from historical data or simulations of ecosystems at different scales. o data on numbers and types of organisms as well as boundaries, resources, and climate. ● Students identify the given explanation(s) to be supported, which include the following ideas: o Some factors have larger effects than do other factors. o Factors are interrelated. o The significance of a factor is dependent on the scale (e.g., a pond vs. an ocean) at which it occurs. ● Students use given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) of ecosystem factors to identify changes over time in the numbers and types of organisms in ecosystems of different scales. ● Students analyze and use the given mathematical and/or computational representations o to identify the interdependence of factors (both living and nonliving) and the resulting effect on carrying capacity. o as evidence to support the explanation and to identify the factors that have the largest effect on the carrying capacity of an ecosystem for a given population.	
Sample Stems	
In 1995, a population of 31 gray wolves was introduced into Yellowstone National Park. The population of the gray wolves fluctuated in the 20-year period after introduction. In 2019 an estimated 80-110 wolves are present in the park. Wolves, elk, and bison are native to Yellowstone, but the wolves disappeared in the 1920s due to excessive hunting. Wolves are primarily carnivores, adn elk and bison are primarily herbivores. A team of scientists monitored the population of wolves in Yellowstone for the first 20 years after their release. The scientists also monitored the populations of elk and bison in Yellowstone for the first 20 years after the wolves' release.	

Figure 1. Number of Wolves in Yellowstone After Release



Source: NPS/Yellowstone Wolf Project

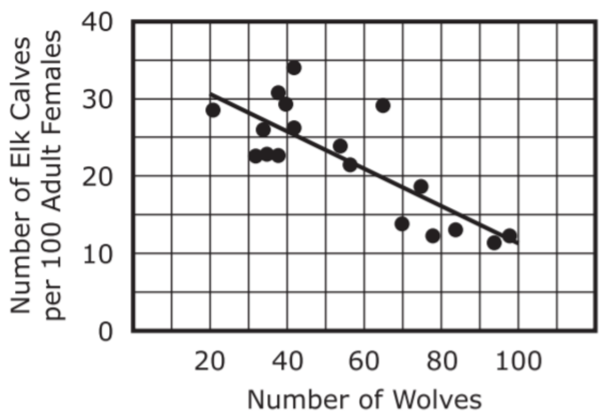
Figure 2. Number of Elk and Bison in Yellowstone After Wolf Release



Source: NPS/Yellowstone Wolf Project

The scientists also tracked the number of elk calves born per 100 elk females compared to the total number of wolves in the park.

FIgure 3. Comparison of the Number of Elk Calves per 100 Elk Females to the Number of Wolves in Yellowstone



Source: NPS/Yellowstone Wolf Project

1. The formula for calculating percent change is below.

$$\frac{\textit{New Value} - \textit{Original value}}{\textit{Original value}} \times 100 = \%\ \textit{change}$$

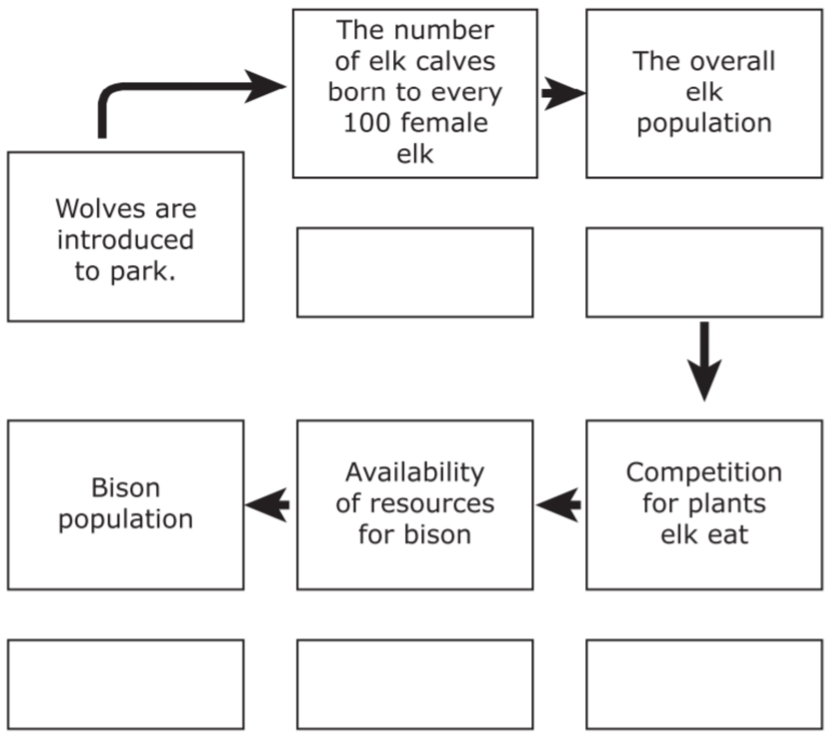
   Part A: Calculate the percent change in the elk population from Year 2 to Year 20.
   Part B: Construct an explanation about the elk population using the data calculated in Part A.
2. Based on the trends in the data, explain the trends in the bison population during this 20-year period.
3. Scientists want to use the data to explain that the wolf population in Yellowstone reached carrying capacity during the 20-year period. Write one piece of evidence from the stimulus in each box to support the explanation.

Years of Rapid Population Growth for Wolves	Years of Stabilization for Wolf Population	Approximate Carrying Capacity of Wolves in Yellowstone

4. Use the data from the stimulus to describe the carrying capacity in elk and bison from Year 1 to Year 20. Circle the correct answer in each box.

Elk Carrying Capacity	Bison Carrying Capacity
did not change /decrease /increase	did not change /decrease /increase

5. The scientists want to use the data to explain the relationship between the wolf introduction and the trends in the elk and bison populations. Write the correct answer in each box. Each answer (increased, decreased, stayed the same) may be used more than once.



6. Both elk and bison are prey for wolves, but one of these prey animals make up 89%-96% of the wolves' diet in Yellowstone.
   Part A: Use the data from the graphs to explain which prey animal most likely fits this description.
   Part B: Use the data to explain how the trends during this 20-year period likely affected the interactions between these organisms in the ecosystem. Support your explanation using data from the graphs.
   Part C: Predict what would likely happen to the ecosystem if this prey population disappeared from Yellowstone as the wolf population once did. Use graphs to describe the effect it would have on both the wolves and the other prey population.

Grades 9-12 LIFE SCIENCE

Life Sciences		9-12.LS2.B.1
Core Idea **Component** **MLS**	**Ecosystems: Interactions, Energy, and Dynamics** **Cycles of Matter and Energy Transfer in Ecosystems** Construct and revise an explanation based on evidence that the processes of photosynthesis, chemosynthesis, and aerobic and anaerobic respiration are responsible for the cycling of matter and flow of energy through ecosystems and that environmental conditions restrict which reactions can occur.	

Expectation Unwrapped	DOK Ceiling
[Clarification Statement: Examples of environmental conditions can include the availability of sunlight or oxygen.] **SCIENCE AND ENGINEERING PRACTICES** **Constructing Explanations and Designing Solutions** ● Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, and peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. **Connections to Nature of Science: Scientific Knowledge Is Open to Revision in Light of New Evidence** ● Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. **DISCIPLINARY CORE IDEAS** **Cycles of Matter and Energy Transfer in Ecosystems** ● Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. **CROSSCUTTING CONCEPTS** **Energy and Matter** ● Energy drives the cycling of matter within and between systems.	3 **Item Format** Selected Response Constructed Response Technology Enhanced

Content Limits/Assessment Boundaries	Stimulus Materials
● Tasks should be limited to conceptual understandings, not the specific mechanisms of rearranging atoms. ● Tasks should not include the specific chemical processes of photosynthesis (e.g., light dependent and independent reactions) or the chemosynthesis of either aerobic (e.g., Kreb's Cycle, glycolysis) or anaerobic respiration. ● Tasks should not include the nitrogen cycle, water cycle, or phosphorus cycle. ● Tasks should not require students to distinguish between credible and non-credible sources.	Graphic organizers, diagrams, graphs, data tables, drawings

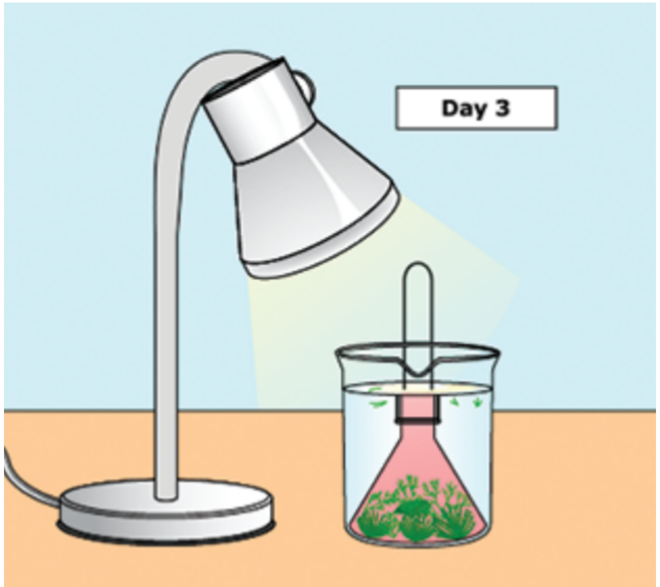
Possible Evidence	
● Students make a claim explaining the phenomena (cycling of matter and flow of energy through ecosystems). ○ Students construct an explanation that includes the following: ▪ Energy from photosynthesis and respiration drives the cycling of matter and flow of energy under aerobic or anaerobic conditions within an ecosystem. ▪ Anaerobic respiration occurs primarily in conditions where oxygen is not available. ● Students identify and describe the evidence to construct the explanation, including the following: ○ All organisms take in matter and rearrange the atoms in chemical reactions. ○ Photosynthesis captures energy in sunlight to create chemical products that can be used as food in cellular respiration. ○ Cellular respiration is the process by which the matter in food (sugars, fats) reacts chemically with other compounds, rearranging the matter to release energy that is used by the cell for essential life processes. ● Students use a variety of valid and reliable sources for the evidence, which may include theories, simulations, peer review, and students' own investigations. ● Students use reasoning to connect evidence, along with the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, to construct their explanation. Students describe the following chain of reasoning used to construct their explanation: ○ Energy inputs to cells occur either by photosynthesis or by taking in food. ○ Since all cells engage in cellular respiration, they must all produce products of respiration. ○ The flow of matter into and out of cells must therefore be driven by the energy captured during photosynthesis or obtained by taking in food and released by respiration. ○ The flow of matter and energy must occur whether respiration is aerobic or anaerobic. ● Given new data or information, students revise their explanation and justify the revision (e.g., recent discoveries of life surrounding deep sea ocean vents have shown that photosynthesis is not the only driver for cycling matter and energy in ecosystems).	
Sample Stems Scientists have observed a decrease in dissolved oxygen levels and a decrease in the level of light in the water in a pound. This seems to be happening because the water is cloudy. They conducted two experiments to test the responses of a local species of pondweed (an aquatic plant) to these changing conditions. Experiment 1: The first part of the experiment measured the effects of light intensity on carbon dioxide absorption and release in pondweed. Two groups of pondweed were submerged in water. One group was put in light, and the other was kept in darkness. The presence of carbon dioxide in water can be detected with a pH indicator called phenol red. Table 1 shows how	

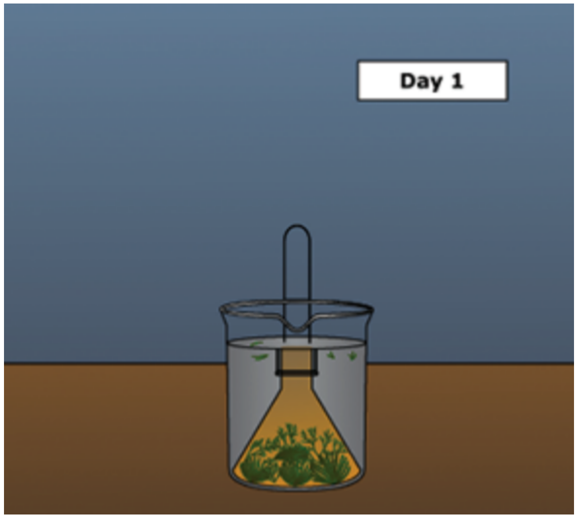
the color of phenol red changes due to pH.

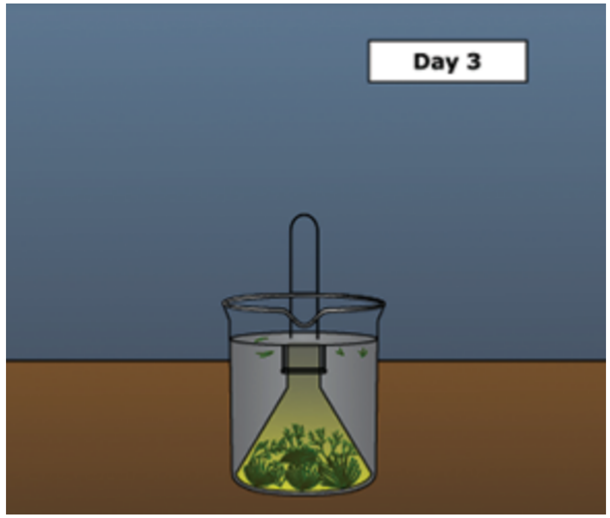
Table 1. Color of Phenol Red with pH Changes

pH	Color of Phenol Red
less than 6.8	yellow
6.8-8.2	orange
greater than 8.2	pink

At the start of the experiment, the water with the phenol red was orange for both groups. After several days, the water of the group in light turned pink and the water of the group in the dark turned yellow.

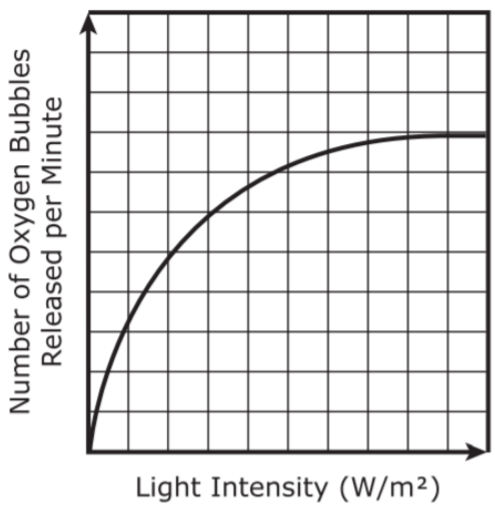






The second part of the experiment tested the effects of light intensity on oxygen released in pondweed. Oxygen release was measured by the formation of bubbles on the surface of the leaves. The results are shown in Figure 1.

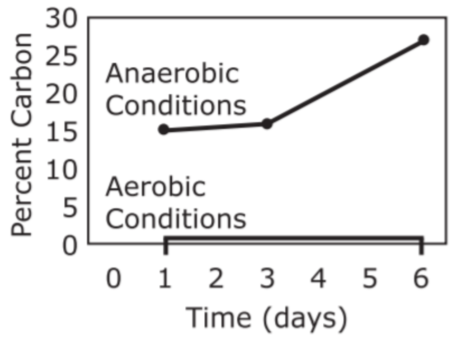
Figure 1. Effects of Light Intensity on Oxygen Release



Experiment 2: The scientists had observed that under certain conditions, this species of pondweed can break down stored starch in their stems into ethanol, lactate, and energy. Two groups of pondweed were submerged in water and placed in

darkness. one group had dissolved oxygen in the environment, and the other did not. For six days, the scientists measured the percentage of carbon in the plant tissues that was used to make ethanol. The results of this study are given in Figure 2.

Figure 2. Percent of Carbon Over Time



Source: T. Sato, et al., *Journal of Experimental Botany*, 2002

1. Based on the data from Experiment 1, explain how light intensity affects pondweed's ability to produce energy for life processes.
2. Explain how the data in Experiment 2 relates to the availability of energy for life processes.
3. The point where the curve on the graph levels off with a constant number of bubbles per minute is (125, 105). Complete the explanation about the availability of oxygen for life processes in Experiment 1. Write the correct answer in the blank.

   Based on the experimental results, exposing the same pondweed plant to a light intensity of 250 W/m^2 should result in a rate of release of ______________ oxygen bubbles per minute.

Grades 9-12 LIFE SCIENCE

Life Sciences		9-12.LS2.B.2
Core Idea	**Ecosystems: Interactions, Energy, and Dynamics**	
Component	**Cycles of Matter and Energy Transfer in Ecosystems**	
MLS	Communicate the pattern of the cycling of matter and the flow of energy among trophic levels in an ecosystem.	

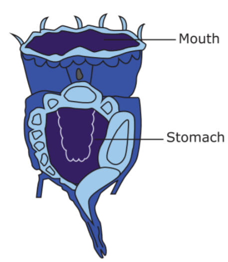
Expectation Unwrapped	**DOK Ceiling**
[Clarification Statement: Emphasis is on using a model of stored energy in biomass to describe the transfer of energy from one trophic level to another, and on atoms and molecules as they move through an ecosystem. Mathematical representation could be, but is not limited to, data that has been manipulated, a data table, a graph, an equation, etc.] **SCIENCE AND ENGINEERING PRACTICES** **Using Mathematical and Computational Thinking** ● Use mathematical representations of phenomena or design solutions to support claims. **DISCIPLINARY CORE IDEAS** **Cycles of Matter and Energy Transfer in Ecosystems** ● Plants or algae form the lowest level of the food web. ● At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. ● Given this inefficiency, there are generally fewer organisms at higher levels of a food web. ● Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. ● The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. ● At each link in an ecosystem, matter and energy are conserved. **CROSSCUTTING CONCEPTS** **Energy and Matter** ● Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.	3 **Item Format** Selected Response Constructed Response Technology Enhanced
Content Limits/Assessment Boundaries	**Stimulus Materials**
● Tasks should be limited to using proportional reasoning to describe the cycling of matter and the follow of energy. ● Tasks should not require students to develop a claim or generate a mathematical model.	Graphic organizers, diagrams, graphs, data

Possible Evidence	tables, drawings
- Students identify and describe the components in the mathematical representations that are relevant to supporting the claims. The components could include relative quantities related to organisms, matter, energy, and the food web in an ecosystem. (e.g. 10% rule) - Students identify the claims about the cycling of matter and energy flow among organisms in an ecosystem. - Students describe how the claims can be expressed as a mathematical relationship in the mathematical representations of the components of an ecosystem. - Students use the mathematical representation(s) of the food web to - describe the transfer of matter (as atoms and molecules) and flow of energy upward between organisms and their environment. - identify the transfer of energy and matter between trophic levels. - identify the relative proportion of organisms at each trophic level by correctly identifying producers as the lowest trophic level and as having the greatest biomass and energy and consumers as decreasing in numbers at higher trophic levels. - Students use the mathematical representation(s) to support the claims that include the idea that matter flows between organisms and their environment. - Students use the mathematical representation(s) to support the claims that include the idea that energy flows from one trophic level to another as well as through the environment. - Students analyze and use the mathematical representation(s) to account for the energy not transferred to higher trophic levels, which is instead used for growth, maintenance, or repair, and/or transferred to the environment, and for the inefficiencies in the transfer of matter and energy.	

Sample Stems

On a field trip, a student collects a sample of lake water and examines it under a microscope. The student sees a microscopic animal with a clearly visible mouth and stomach. Her teacher identifies the organism as a type of zooplankton.

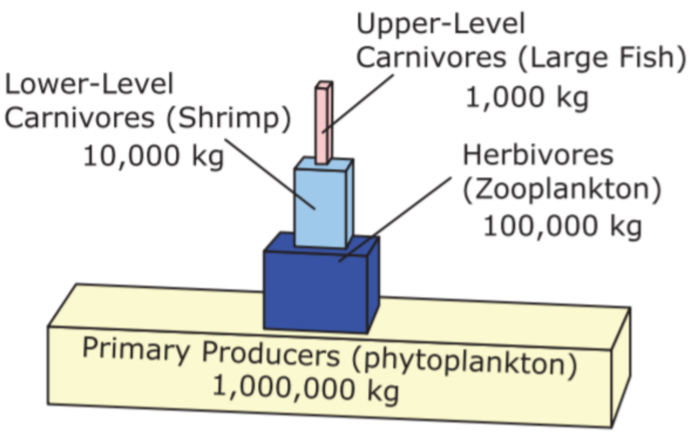
Figure 1. Zooplankton



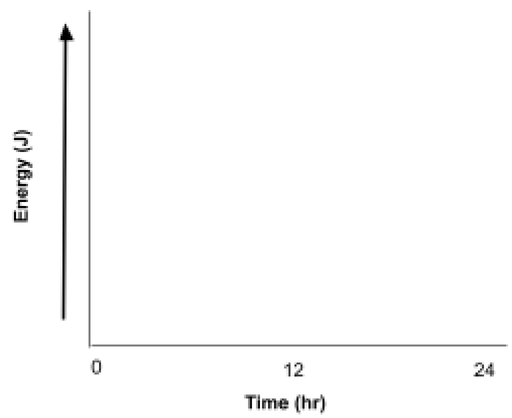
The zooplankton takes water into its mouth, which it then filters, sending tiny particles of photosynthetic algae (phytoplankton) to its stomach for digestion. The student observes the feeding activity of the zooplankton, although the particles they are consuming are so small they remain invisible under the student's microscope.

The student also observes zooplankton of varying sizes. The student cannot measure absolute size, but observes individuals within a single species ranging from a smallest observed size to three times that size. Her teacher explains that in addition to natural size variation, zooplankton get larger as they mature. The student researches the ecological role of zooplankton and finds a simplified model of biomass at different trophic levels in ecosystems which includes zooplankton:

Figure 2. Aquatic Biomass Pyramid



1. Over a 24-hour time period, the student periodically observes the zooplankton consuming phytoplankton. The student wants to use this observation to graph the amount of energy taken in by the zooplankton over the time period. Draw the line on the graph below.



2. The student uses the information in Figure 2 to generate an equation representing the mass of living material a trophic level can support in the trophic level above it.
    - The term (t) represents the mass of living material in a trophic level.
    - The term (t+1) represents the mass of living material in the trophic level above.

   Complete the student's equation below. Write the correct answer in the box.

$$(t + 1) = \boxed{}(t)$$

3. The student compares photographs of zooplankton at different stages of maturation, observing that body size increases between the earliest and latest stages. Circle the correct answer from each list to complete the sentences.

   The change in body mass through growth largely comes from molecules synthesized by (zooplankton during cell division/phytoplankton during photosynthesis/phytoplankton during ATP production). The synthesized molecules must include additional matter from a variety of sources because this process does not produce (heat energy/carbon dioxide during respiration/all substances needed for growth).
4. The student takes part in another study of the lake ecosystem. As part of this study, 250 grams of zooplankton are collected from lake water.
   Part A: Identify the approximate number of grams of phytoplankton the ecosystem must include in order to support the zooplankton sample.
   Part B: Explain your answer to Part A.
   Part C: Identify the approximate number of grams of lower-level carnivores the sample can support.
   Part D: Explain your answer to Part C.
   Part E: Explain the relationships between the masses found in Part A and Part C in terms of the cycling of energy in the ecosystem.

Life Sciences		9-12.LS2.B.3
Core Idea	**Ecosystems: Interactions, Energy, and Dynamics**	
Component	**Cycles of Matter and Energy Transfer in Ecosystems**	
MLS	Use a model that illustrates the roles of photosynthesis, cellular respiration, decomposition, and combustion to explain the cycling of carbon in its various forms among the biosphere, atmosphere, hydrosphere, and geosphere.	

Expectation Unwrapped	**DOK Ceiling**
	3
[Clarification Statement: The primary forms of carbon include carbon dioxide, hydrocarbons, waste, and biomass. Examples of models could include simulations and mathematical and conceptual models.] **SCIENCE AND ENGINEERING PRACTICES** **Developing and Using Models** ● Develop a model based on evidence to illustrate the relationships between systems or components of a system. **DISCIPLINARY CORE IDEAS** **Cycles of Matter and Energy Transfer in Ecosystems** ● Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. **Energy in Chemical Processes** ● The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. **CROSSCUTTING CONCEPTS** **Systems and System Models** ● Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.	**Item Format** Selected Response Constructed Response Technology Enhanced
Content Limits/Assessment Boundaries	**Stimulus Materials**
● Tasks should avoid the specific chemical steps of photosynthesis, respiration, decomposition, and combustion.	Graphic organizers, diagrams, graphs, data tables, drawings

Possible Evidence

- Students use evidence from a given model in which they identify and describe the relevant components, including the following:
  - The inputs and outputs of photosynthesis
  - The inputs and outputs of cellular respiration
  - The biosphere, atmosphere, hydrosphere, and geosphere
- Students describe relationships between components of the given model, including the following:
  - The exchange of carbon (through carbon-containing compounds) between organisms and the environment
  - The role of storing carbon in organisms (in the form of carbon-containing compounds) as part of the carbon cycle
- Students describe the contribution of photosynthesis and cellular respiration to the exchange of carbon within and among the biosphere, atmosphere, hydrosphere, and geosphere in the given model.
- Students make a distinction between the model's simulation and the actual cycling of carbon via photosynthesis and cellular respiration.

Sample Stems

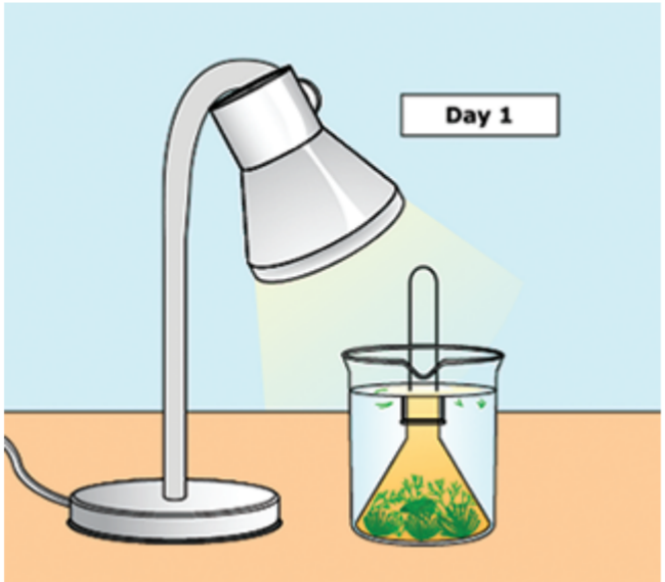
Scientists have observed a decrease in dissolved oxygen levels and a decrease in the level of light in the water in a pound. This seems to be happening because the water is cloudy. They conducted two experiments to test the responses of a local species of pondweed (an aquatic plant) to these changing conditions.

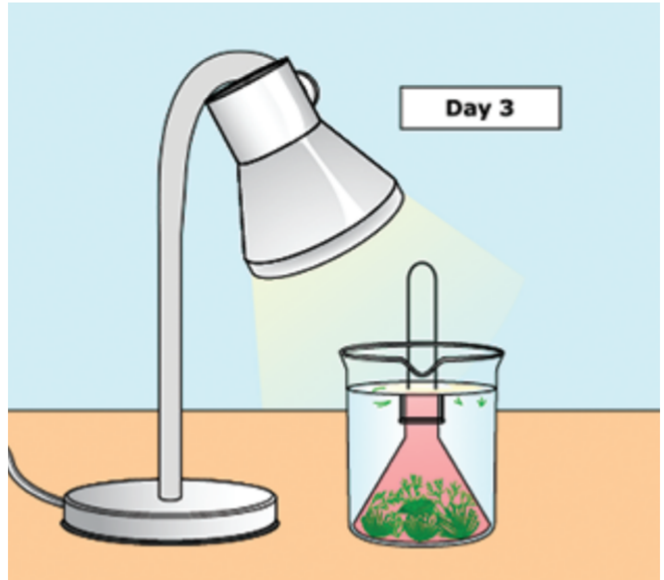
Experiment 1: The first part of the experiment measured the effects of light intensity on carbon dioxide absorption and release in pondweed. Two groups of pondweed were submerged in water. One group was put in light, and the other was kept in darkness. The presence of carbon dioxide in water can be detected with a pH indicator called phenol red. Table 1 shows how the color of phenol red changes due to pH.

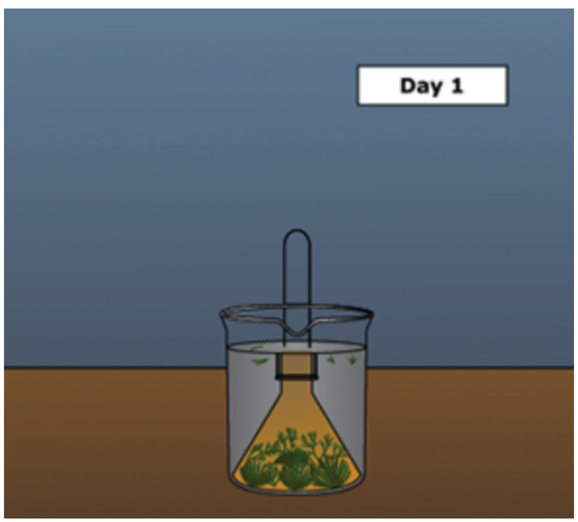
Table 1. Color of Phenol Red with pH Changes

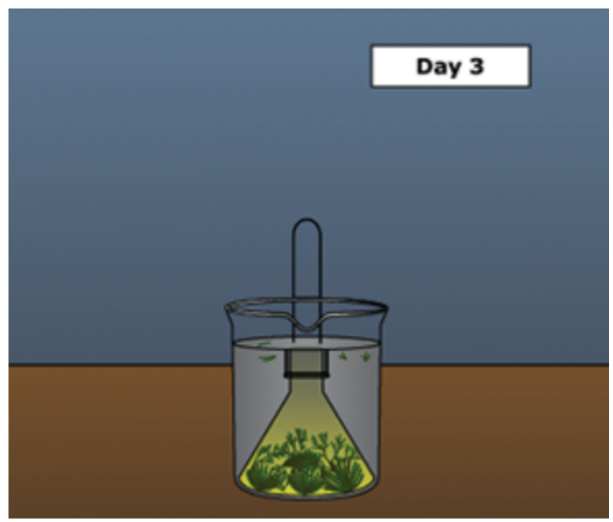
pH	Color of Phenol Red
less than 6.8	yellow
6.8-8.2	organe
greater than 8.2	pink

At the start of the experiment, the water with the phenol red was organe for both groups. After several days, the water of the group in light turned pink and the water of the group in the dark turned yellow.



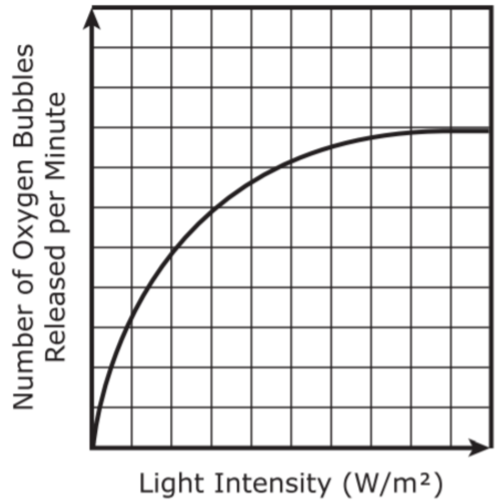






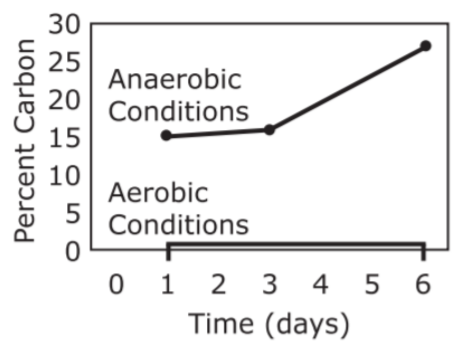
The second part of the experiment tested the effects of light intensity on oxygen released in pondweed. Oxygen release was measured by the formation of bubbles on the surface of the leaves. The results are shown in Figure 1.

Figure 1. Effects of Light Intensity on Oxygen Release



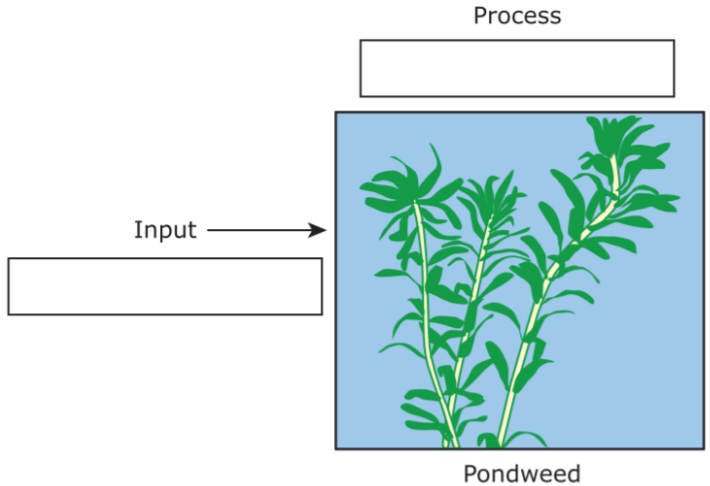
Experiment 2: The scientists had observed that under certain conditions, this species of pondweed can break down stored starch in their stems into ethanol, lactate, and energy. Two groups of pondweed were submerged in water and placed in darkness. one group had dissolved oxygen in the environment, and the other did not. For six days, the scientists measured the percentage of carbon in the plant tissues that was used to make ethanol. The results of this study are given in Figure 2.

Figure 2. Percent of Carbon Over Time



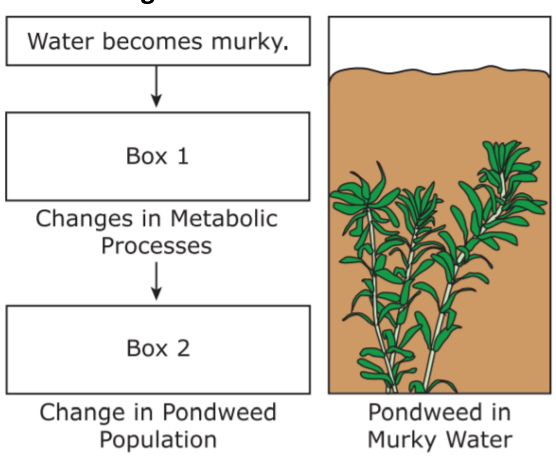
Source: T. Sato, et al., *Journal of Experimental Botany*, 2002

1. A student is working on a model to explain what processes are taking place in the pondweed when the phenol red turns from orange to yellow. The student decides which substance is the input, and what process is occurring. Write the correct answer in each box of the model.



2. Eutrophication most commonly occurs when nutrients from fertilizers enter the pond water by surface runoff. A student reads that under eutrophic conditions, water in a pond becomes murky and oxygen deprived. The student uses the experimental data to model the effects of these conditions on pondweed growing in a pond.

Figure 3. Student's Model



Part A: Write a description about what is happening to photosynthesis in Box 1.
Part B: Explain what is happening with the pondweed population in Box 2 and why.
Part C: Explain how the contents of Boxes 1 and 2 affect carbon cycling in the pond ecosystem.

Grades 9-12 LIFE SCIENCE

Life Sciences		9-12.LS2.C.1
Core Idea	**Ecosystems: Interactions, Energy, and Dynamics**	
Component	**Ecosystems Dynamics, Functioning, and Resilience**	
MLS	Evaluate the claims, evidence, and reasoning that the interactions in ecosystems maintain relatively consistent populations of species while conditions remain stable, but changing conditions may result in new ecosystem dynamics.	

Expectation Unwrapped	DOK Ceiling
[Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise. New ecosystem dynamics should be interpreted as characteristics of that new ecosystem.] **SCIENCE AND ENGINEERING PRACTICES** **Engaging in Argument from Evidence** ● Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. **Connections to Nature of Science: Scientific Knowledge Is Open to Revision in Light of New Evidence** ● Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation. **DISCIPLINARY CORE IDEAS** **Ecosystems Dynamics, Functioning, and Resilience** ● A complex set of interactions within an ecosystem can keep the ecosystem's numbers and types of organisms relatively constant over long periods of time under stable conditions. ● If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient) as opposed to becoming a very different ecosystem. ● Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. **CROSSCUTTING CONCEPTS** **Stability and Change** ● Much of science deals with constructing explanations of how things change and how they remain stable. Refer to Engineering, Technology, and Application of Science 9-12.ETS1.B.1.	3 **Item Format** Selected Response Constructed Response Technology Enhanced

Content Limits/Assessment Boundaries	Stimulus Materials
● Tasks should provide students with a specific claim to evaluate. Students are not required to generate their own claims. ● Tasks should include adequate background information on an ecosystem to draw any necessary conclusions.	Graphic organizers, diagrams, graphs, data tables, drawings
Possible Evidence ● Students identify the given explanation that is supported by the claims, evidence, and reasoning to be evaluated, and which includes the following idea: The complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. o From the given materials, students identify ▪ the claims to be evaluated. ▪ the evidence to be evaluated. ▪ the reasoning to be evaluated. ● Students identify and describe additional evidence (in the form of data, information, or other appropriate forms) that was not provided but is relevant to the explanation and to evaluating the given claims, evidence, and reasoning: o The factors that affect biodiversity o The relationships between species and the physical environment in an ecosystem o Changes in the numbers of species and organisms in an ecosystem that has been subject to a modest or extreme change in ecosystem conditions ● Students describe the strengths and weaknesses of the given claim in accurately explaining a particular response of biodiversity to a changing condition, based on an understanding of the factors that affect biodiversity and the relationships between species and the physical environment in an ecosystem. ● Students use their additional evidence to assess the validity and reliability of the given evidence and its ability to support the argument that resiliency of an ecosystem is subject to the degree of change in the biological and physical environment of an ecosystem. ● Students assess the logic of the reasoning, including the relationship between degree of change and stability in ecosystems, and the utility of the reasoning in supporting the explanation of how o modest biological or physical disturbances in an ecosystem result in maintenance of relatively consistent numbers and types of organisms. o extreme fluctuations in conditions or the size of any population can challenge the functioning of ecosystems in terms of resources and habitat availability and can even result in a new ecosystem.	

Sample Stems

Wild sheep on California's Santa Cruz Island were originally brought to the island by humans. Researchers spent several years studying the environmental impact of the wild sheep population on the island. They found that as the sheep population increased, the sheep overgrazed and trampled native plant species, resulting in multiple ecological and physical changes. Plant growth was slowed or prevented and bare ground patches appeared. Plant growth was compared with sheep population density, yielding the data in Table 1.

Table 1. Impact of Sheep Population Density on Plant Growth

Sheep Population Density (individuals per hectare)	Sheep Impact on Plant Growth	Percent of Area Impacted
0.2	light	47
0.9	moderate	36
2.1	severe	17

Source: D. Van Vuren & B.E. Coblentz, *Biological Conservation,* 1987

In areas with light impact, shrubs and grasses were largely undisturbed, though there were a few small areas of bare soil. In areas with moderate impact, there was some evidence of consumption of shrubs and grasses, some areas of bare soil, and in places sheep traffic had worn trails through vegetation. In areas with severe impact, most accessible vegetation was consumed, there were extensive bare soil areas, and sheep trails that exposed rock were not uncommon. In the bare patches, erosion accelerated, resulting in the formation of steep inclines. The amount of erosion, as characterized by ground properties, is given in Table 2.

Table 2. Relationship Between Sheep Impact on Plant Growth and Ground Properties

Sheep Impact on Plant Growth	Plant Cover (%)	Bare Dirt (%)	Exposed Bedrock (%)
light	90	9	1
moderate	75	22	3
severe	60	35	5

Source: D. Van Vuren & B.E. Coblentz, *Biological Conservation,* 1987

After the introduction of sheep, native bird population showed a loss of density and diversity. **Table 3. Relationship between Sheep Impact on Plant Growth and Bird Populations**	

Sheep Impact on Plant Growth	Bird Density (number of birds per square kilometer)	Bird Diversity (number of species present)
light	506	17
moderate	214	8

Source: D. Van Vuren & B.E. Coblentz, *Biological Conservation,* 1987

1. A scientist claims that sheep activities are impacting the entire food web of Santa Cruz Island. Support or refute this claim using evidence from the passage.
2. The scientist then claims that once sheep are present, exact sheep population density has little impact on an ecosystem. Support or refute this claim using evidence from the passage.
3. A scientist argues that changes produced by the sheep are destabilizing the current ecosystem on Santa Cruz Island, leading to formation of a new type of ecosystem.

   Part A: Identify two pieces of data from Table 2 that provide evidence that sheep are significantly changing the physical landscape of the island.

   Part B: Based on the data, describe the process that changes the physical landscape.

   Part C: Evaluate whether the scientist's argument is valid. Explain your evaluation.

Grades 9-12 LIFE SCIENCE

Life Sciences		9-12.LS2.C.2
Core Idea	**Ecosystems: Interactions, Energy, and Dynamics**	
Component	**Ecosystems Dynamics, Functioning, and Resilience**	
MLS	Design, evaluate, and/or refine solutions that positively impact the environment and biodiversity.	

Expectation Unwrapped

[Clarification Statement: Examples of solutions may include captive breeding programs, habitat restoration, pollution mitigation, energy conservation, agriculture and mining programs, and ecotourism.]

SCIENCE AND ENGINEERING PRACTICES

Constructing Explanations and Designing Solutions

- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

DISCIPLINARY CORE IDEAS

Ecosystems, Dynamics, Functioning, and Resilience

- Anthropogenic changes (changes induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.

Biodiversity and Humans

- Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction).
- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth.
- Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (Note: This Disciplinary Core Idea is also addressed by HS- LS4-6.)

Developing Possible Solutions

- When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability, and aesthetics and to consider social, cultural, and environmental impacts.

DOK Ceiling

3

Item Format

Selected Response
Constructed Response
Technology Enhanced

<table>
<tr><td>
<u>CROSSCUTTING CONCEPTS</u>
Stability and Change
● Much of science deals with constructing explanations of how things change and how they remain stable.

Refer to Engineering, Technology, and Application of Science 9-12.ETS.1.A.2.
</td><td></td></tr>
<tr><td>
<u>Content Limits/Assessment Boundaries</u>

● Tasks should include a scenario. Students are not required to generate their own scenario.
● Tasks do not need to address all three parts of the solution: define, evaluate, or refine.
</td><td rowspan="3">
<u>Stimulus Materials</u>

Graphic organizers, diagrams, graphs, data tables, drawings
</td></tr>
<tr><td>
<u>Possible Evidence</u>

● Students design a solution that increases positive impact on the environment and biodiversity and that relies on scientific knowledge of the factors affecting changes and stability in biodiversity. Examples of factors include, but are not limited to,
○ overpopulation,
○ overexploitation,
○ habitat destruction,
○ pollution,
○ introduction of invasive species, and
○ changes in climate.
● Students describe the ways the proposed solution increases the positive impacts on the environment and biodiversity.
● Students describe and quantify (when appropriate) the criteria (amount of the effect as it impacts the environment and biodiversity) and limitations (constraints) (for example, cost, human needs, and environmental impacts) for the solution to the problem, along with the trade-offs in the solution.
● Students evaluate the proposed solution for its impact on overall environmental stability and changes.
● Students evaluate the cost, safety, and reliability, as well as social, cultural, and environmental impacts, of the proposed solution that will benefit an ecosystem.
● Students refine the proposed solution by prioritizing the criteria and making trade-offs as necessary to further positively impact the environment and biodiversity while addressing human needs.
</td></tr>
<tr><td>
<u>Sample Stems</u>

Wild sheep on California’s Santa Cruz Island were originally brought to the island by humans. Researchers spent several years studying the environmental impact of the wild sheep population on the island. They found that as the sheep population increased, the sheep overgrazed and trampled native plant species, resulting in multiple ecological and physical changes. Plant
</td></tr>
</table>

growth was slowed or prevented and bare ground patches appeared. Plant growth was compared with sheep population density, yielding the data in Table 1.

Table 1. Impact of Sheep Population Density on Plant Growth

Sheep Population Density (individuals per hectare)	Sheep Impact on Plant Growth	Percent of Area Impacted
0.2	light	47
0.9	moderate	36
2.1	severe	17

In areas with light impact, shrubs and grasses were largely undisturbed, though there were a few small areas of bare soil. In areas with moderate impact, there was some evidence of consumption of shrubs and grasses, some areas of bare soil, and in places sheep traffic had worn trails through vegetation. In areas with severe impact, most accessible vegetation was consumed, there were extensive bare soil areas, and sheep trails that exposed rock were not uncommon. In the bare patches, erosion accelerated, resulting in the formation of steep inclines. The amount of erosion, as characterized by ground properties, is given in Table 2.

Table 2. Relationship Between Sheep Impact on Plant Growth and Ground Properties

Sheep Impact on Plant Growth	Plant Cover (%)	Bare Dirt (%)	Exposed Bedrock (%)
light	90	9	1
moderate	75	22	3
severe	60	35	5

After the introduction of sheep, native bird population showed a loss of density and diversity.

Table 3. Relationship between Sheep Impact on Plant Growth and Bird Populations

Sheep Impact on Plant Growth	Bird Density (number of birds per square kilometer)	Bird Diversity (number of species present)
light	506	17
moderate	214	8

1. One policy planner would like to maintain a sheep population on Santa Cruz Island, but at a density low enough that sheep will show less than moderate impact on plant growth. Describe the highest population density acceptable under this plan. 2. **Part A:** A student is interning with a conservation group that seeks to restore the size and diversity of bird populations on Santa Cruz Island. The student designs a plan of a. planting seeds and placing artificial turf on the island. b. introducing new organisms that compete with birds. c. reducing and controlling the size of sheep populations. **Part B:** Construct an explanation the student might use to describe what the overall ecosystem can be expected to show when this solution from Part A is implemented. 3. One conservation plan for the island proposes reducing sheep population density to 1.5 individuals per hectare in all areas where it is above 1.5. **Part A:** Based on the evidence in Tables 1 and 2, describe whether or not this solution would be beneficial? **Part B:** Identify the status of impact the sheep would have on plant growth. Source of data: D. Van Vuren & B.E. Coblentz, *Biological Conservation,* 1987	

Grades 9-12 LIFE SCIENCE

Life Sciences		9-12.LS3.A.1
Core Idea Component MLS	**Heredity: Inheritance and Variation of Traits** **Inheritance of Traits** Develop and use models to clarify relationships about how DNA in the form of chromosomes is passed from parents to offspring through the processes of meiosis and fertilization in sexual reproduction.	
Expectation Unwrapped **SCIENCE AND ENGINEERING PRACTICES** **Developing and Using Models** ● Develop a model based on evidence to illustrate the relationships between systems or components of a system. **DISCIPLINARY CORE IDEAS** **Structure and Function** ● All cells contain genetic information in the form of DNA molecules. ● Genes are regions in the DNA that contain the instructions that code for the formation of proteins. **Inheritance of Traits** ● Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. ● The instructions for forming species' characteristics are carried in DNA. ● All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. ● Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. **CROSSCUTTING CONCEPTS** **Cause and Effect** ● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.		**DOK Ceiling** 3 **Item Format** Selected Response Constructed Response Technology Enhanced
Content Limits/Assessment Boundaries ● Tasks should focus on the division of DNA to create haploid gametes, as well as the combination of gametes in the process of fertilization to create a diploid cell. ● Tasks should avoid rote memorization of the phases of meiosis or the biochemical mechanisms of specific steps in the process.		**Stimulus Materials**

- Tasks should avoid the concepts of independent assortment and crossing over.

Graphic organizers, diagrams, graphs, data tables, drawings

Possible Evidence

- Students develop a model in which they identify and describe the relevant parts of the process (e.g, DNA in the form of chromosomes, gametes, fertilization).
- In the model, students describe the relationships between the components, including the following:
  - The cause and effect relationship between DNA, the proteins it codes for, and the resulting traits observed in an organism
  - The process of meiosis
  - The process of fertilization through sexual reproduction
- Students use the model to illustrate the interaction between components of the model and the resulting traits being passed from generation to generation through sexual reproduction. A pedigree is an example of a model that students could use.
- Students make a distinction between the accuracy of the model and actual body processes.

Sample Stems

Humans have a close working relationship with horses. As a result, many horse disorders have been thoroughly researched. Over the summer, a student serves as an intern at a local veterinary office that specializes in horses. Throughout this experience, the student observes horses with a smaller than average body size, multiple failed pregnancies, and multiple infections.

Table 1. Summary of Observations of Horses

Horse	Symptoms	Occurs in Families?	Disorder
1	small body size, reproductive system not fully developed	no	Equine Turner Syndrome (ETS)
2	pregnancy failure	no	Repeated Early Embryonic Loss (REEL)
3	immune system failure, lack of white blood cells	yes	Severe Combined Immunodeficiency (SCID)

1. Although REEL does not occur in families, it does have a genetic basis, and transcription and translation are affected. Given its generic basis, construct a question that could best guide further research into the causes of its symptoms.
2. Use the phrases below to construct a model describing the relationship between the microscopic causes and symptoms of SCID.
   - change in the nucleotide sequence of DNA
   - change in the triplet mRNA code
   - change in the protein produced
   - change in the components of the cell membrane

- decrease in immune system function
- nervous system performs immune system functions

Cause at Microscopic Level	Effect at Microscopic Level	Symptom

3. The student concludes that the disorder of Horse 1 must result from errors in (mitosis/meiosis/ATP production/cell membrane formation). The effect of these errors is to cause problems with newly formed (ATP/RNA/membranes/zygotes), which can be concluded based on the fact that horses with this disorder cannot produce offspring.
4. The student researches another horse disorder. She reads that the disorder affects the structure of one protein. The second disorder also runs in families. Similar to SCID, the disorder must be inherited from both parents, neither of whom shows symptoms of the disorder.
   The student argues that this horse disorder is similar to SCID in that it is (caused by a virus/an inherited condition/caused by a bacterial infection), and also because it requires (2/4) (copies of a gene/copies of a protein) in order to produce symptoms.

Grades 9-12 LIFE SCIENCE

<table>
<tr><th colspan="2">Life Sciences</th><th>9-12.LS3.B.1</th></tr>
<tr><td>Core Idea
Component
MLS</td><td colspan="2">Heredity: Inheritance and Variation of Traits
Variation of Traits
Compare and contrast asexual and sexual reproduction with regard to genetic information and variation in offspring.</td></tr>
<tr><td colspan="2">
<u>Expectation Unwrapped</u>
<u>SCIENCE AND ENGINEERING PRACTICES</u>
Developing a Model
Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.
Obtaining, Evaluating and Communicating Information
Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats, including orally, graphically, textually, and mathematically.
<u>DISCIPLINARY CORE IDEAS</u>
Variation of Traits
In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation.
Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation.
Environmental factors can also cause mutations in genes, and viable mutations are inherited.
Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.
Characteristics of Asexual and Sexual Reproduction
Asexual reproduction produces genetically identical offspring, whereas sexual reproduction produces genetic variation.
<u>CROSSCUTTING CONCEPTS</u>
Cause and Effect
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
</td><td> <u>DOK Ceiling</u>
3 <u>Item Format</u> Selected Response
Constructed Response
Technology Enhanced</td></tr>
<tr><td colspan="2"> <u>Content Limits/Assessment Boundaries</u>
Tasks should focus on comparing and contrasting the processes of sexual and asexual reproduction.
Tasks should avoid the different types of sexual and asexual reproduction (e.g., budding, internal, external, binary fusion).</td><td> <u>Stimulus Materials</u> Graphic organizers, diagrams, graphs, data</td></tr>
</table>

Possible Evidence

- Students develop a visual representation in which they compare and contrast asexual and sexual reproduction (e.g., mitosis, meiosis, haploid, diploid, genetic diversity).
- Students describe the relationships between sexual and asexual reproduction:
  - The relationship between mitosis and asexual reproduction
  - The relationship between meiosis and sexual reproduction
  - The process of fertilization through sexual reproduction

tables, drawings

Sample Stems

Humans have a close working relationship with horses. As a result, many horse disorders have been thoroughly researched. Over the summer, a student serves as an intern at a local veterinary office that specializes in horses. Throughout this experience, the student observes horses with a smaller than average body size, multiple failed pregnancies, and multiple infections.

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3	immune system failure, lack of white blood cells	yes	Severe Combined Immunodeficiency (SCID)

1. Using the data in Table 1 about SCID, construct a question that would best guide further research.
2. Although REEL does not occur in families, it does have a genetic basis, and transcription and translation are affected. Given its generic basis, construct a question that could best guide further research into the causes of its symptoms.
3. The student concludes that the disorder of Horse 1 must result from errors in (mitosis/meiosis/ATP production/cell membrane formation). The effect of these errors is to cause problems with newly formed (ATP/RNA/membranes/zygotes), which can be concluded based on the fact that horses with this disorder cannot produce offspring.
4. The student researches another horse disorder. She reads that the disorder affects the structure of one protein. The second disorder also runs in families. Similar to SCID, the disorder must be inherited from both parents, neither of whom shows symptoms of the disorder.

   The student argues that this horse disorder is similar to SCID in that it is (caused by a virus/an inherited condition/caused by a bacterial infection), and also because it requires (2/4) (copies of a gene/copies of a protein) in order to produce symptoms.

Grades 9-12 LIFE SCIENCE

Life Sciences		9-12.LS3.B.2
Core Idea Component MLS	**Heredity: Inheritance and Variation of Traits** **Variation of Traits** Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.	

Expectation Unwrapped

[Clarification Statement: Emphasis is on conceptual understanding that changes in genetic material may or may not result in making different proteins.]

SCIENCE AND ENGINEERING PRACTICES

Developing and Using Models

- Use a model based on evidence to illustrate the relationships between systems or between components of a system.

DISCIPLINARY CORE IDEAS

Variation of Traits

- In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation.
- Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation.
- Environmental factors can also cause mutations in genes, and viable mutations are inherited.
- Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.

CROSSCUTTING CONCEPTS

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable.

Systems and System Models

- Models (e.g., physical, mathematical, computer) can be used to simulate systems and interactions—including energy, matter and information flows—within and between systems at different scales.

DOK Ceiling

3

Item Format

Selected Response
Constructed Response
Technology Enhanced

<table>
<tr><th>Content Limits/Assessment Boundaries</th><th>Stimulus Materials</th></tr>
<tr><td>

- Tasks should provide students with adequate background information for any given genetic disorder.
- Tasks should avoid identifying specific types of mutations (e.g., frameshift, point), specific changes at the molecular level, and the mechanisms for protein synthesis.

</td><td rowspan="3">Graphic organizers, diagrams, graphs, data tables, drawings</td></tr>
<tr><td>

Possible Evidence

- Students develop a model in which they identify and describe the following:
  - Structural changes to DNA
  - The effects of the structural changes to DNA
- In the model, students describe the relationships between components, including the relationship between genotype and phenotype.
- Students use the model to illustrate the structure and function of the organism and the organism's overall fitness.
- Students make a distinction between the accuracy of the model and actual body processes.

</td></tr>
<tr><td>

Sample Stems

Humans have a close working relationship with horses. As a result, many horse disorders have been thoroughly researched. Over the summer, a student serves as an intern at a local veterinary office that specializes in horses. Throughout this experience, the student observes horses with a smaller than average body size, multiple failed pregnancies, and multiple infections.

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3	immune system failure, lack of white blood cells	yes	Severe Combined Immunodeficiency (SCID)

1. Use the phrases below to construct a model describing the relationship between the microscopic causes and symptoms of SCID.
   - change in the nucleotide sequence of DNA
   - change in the triplet mRNA code
   - change in the protein produced
   - change in the components of the cell membrane
   - decrease in immune system function

</td></tr>
</table>

- nervous system performs immune system functions

Cause at Microscopic Level	Effect at Microscopic Level	Symptom

2. The student concludes that the disorder of Horse 1 must result from errors in (mitosis/meiosis/ATP production/cell membrane formation). The effect of these errors is to cause problems with newly formed (ATP/RNA/membranes/zygotes), which can be concluded based on the fact that horses with this disorder cannot produce offspring.
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   The student argues that this horse disorder is similar to SCID in that it is (caused by a virus/an inherited condition/caused by a bacterial infection), and also because it requires (2/4) (copies of a gene/copies of a protein) in order to produce symptoms.

Life Sciences		9-12.LS3.B.3
Core Idea Component MLS	**Heredity: Inheritance and Variation of Traits** **Variation of Traits** Make and defend a claim that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) mutations occurring during replication, and/or (3) mutations caused by environmental factors.	

Expectation Unwrapped	**DOK Ceiling**
[Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs (e.g., crossing over, independent assortment, mutations from replication, mutations from environmental factors).] **SCIENCE AND ENGINEERING PRACTICES** **Engaging in Argument from Evidence** ● Make and defend a claim based on evidence about the natural world that reflects scientific knowledge and student-generated evidence. **DISCIPLINARY CORE IDEAS** **Variation of Traits** ● In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. ● Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. ● Environmental factors can also cause mutations in genes, and viable mutations are inherited. ● Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. **CROSSCUTTING CONCEPTS** **Cause and Effect** ● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.	3 **Item Format** Selected Response Constructed Response Technology Enhanced
Content Limits/Assessment Boundaries	**Stimulus Materials**
● Tasks should avoid the phases of meiosis or the biochemical mechanism (e.g., centrioles, spindle fibers) of specific steps in the process.	

Possible Evidence	Graphic organizers, diagrams, graphs, data tables, drawings

• Students make a claim that includes the idea that inheritable genetic variations may result from
  ○ new genetic combinations through meiosis,
  ○ viable errors occurring during replication, and
  ○ mutations caused by environmental factors.
• Students identify and describe evidence that supports the claim, including the following:
  ○ Variations in genetic material naturally result during meiosis when corresponding sections of chromosome pairs exchange places.
  ○ Genetic mutations can occur due to errors during replication and/or environmental factors.
  ○ Genetic material is inheritable.
• Students use scientific knowledge, literature, student-generated data (e.g., may include by not limited to, comparison of RNA strand to DNA, data collected through a technology-enhanced computer simulation), simulations, and/or other sources for evidence.
• Students identify the following strengths and weaknesses of the evidence used to support the claim:
  ○ Types and numbers of sources
  ○ Sufficiency to make and defend the claim and to distinguish between causal and correlational relationships
  ○ Validity and reliability of the evidence
• Students use reasoning to describe links between the evidence and claim, including the following:
  ○ Genetic mutations produce genetic variations between cells or organisms.
  ○ Genetic variations produced by mutation and meiosis can be inherited.
• Students use reasoning and valid evidence to describe how new combinations of DNA can arise from several sources, including meiosis, errors during replication, and mutations caused by environmental factors.
• Students defend a claim against counterclaims and critique by evaluating counterclaims and by describing the connections between the relevant and appropriate evidence and the strongest claim.	

Sample Stems **Humans and Horses** Humans have a close working relationship with horses. As a result, many horse disorders have been thoroughly researched. Over the summer, a student serves as an intern at a local veterinary office that specializes in horses. Throughout this experience, the student observes horses with a smaller than average body size, multiple failed pregnancies, and multiple infections. **Table 1. Summary of Observations of Horses**	

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1. The student researches another horse disorder. She reads that the disorder affects the structure of one protein. The second disorder also runs in families. Similar to SCID, the disorder must be inherited from both parents, neither of whom shows symptoms of the disorder.

   The student argues that this horse disorder is similar to SCID in that it is (caused by a virus/an inherited condition/caused by a bacterial infection), and also because it requires (2/4) (copies of a gene/copies of a protein) in order to produce symptoms.

<u>Wisconsin Fast Plants</u>

It has been observed that the heights of Wisconsin Fast Plants vary within a population. Fast Plants are a specially bred type of *Brassica rapa* plant which grow very quickly, reaching maturity in 5 weeks instead of 6 months. They reproduce sexually. A student orders Fast Plant seeds to perform a science investigation. The student grows 24 plants, and measures their heights 14 days after planting. The information is summarized in Table 1.

Table 1. Plant Heights After 14 Days (in centimeters)

14	13	31	6	5	15	15	12	16	14	15	15
13	15	12	28	16	30	15	15	14	17	14	15

Height in Fast Plants is determined by the genes *EIN* and *ROS*. A mutation of one of these genes will produce a plant with an unusual height. Fast Plants expressing the recessive allele *EIN* grow taller than usual. Fast Plants expressing the recessive allele *ROS* grow shorter than usual.

1. The student crosses plant A, which has a height of 14 cm, with plant B, which has a height of 15 cm. Most of the offspring are normal height and the others are short. The student claims that crossing plant A and plant C, which has a height of 6 cm, can only produce offspring with normal or short phenotypes. Using R as dominant and r as recessive, complete the sentence below.

Plant A must have the genotype (RR / Rr / rr) and plant C must have the genotype (RR / Rr / rr). During reproduction of Plant A and Plant C, the process of (natural selection / environmentally-induced mutation / genetic recombination) can result in offspring with normal or short phenotypes. 2. A group of Fast Plants with the same mix of height genes is grown on a plot of land with abundant soil nutrients, water, and light. The plot of land is exposed to a bird species that preys on tall plants. Explain how the incidence of the detrimental trait would change over time.	

Grades 9-12 LIFE SCIENCE

Life Sciences		9-12.LS3.B.4
Core Idea	**Heredity: Inheritance and Variation of Traits**	
Component	**Variation of Traits**	
MLS	Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.	

Expectation Unwrapped

[Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.]

SCIENCE AND ENGINEERING PRACTICES
Analyzing and Interpreting Data
- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.

DISCIPLINARY CORE IDEAS
Variation of Traits
- Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.

CROSSCUTTING CONCEPTS
Scale, Proportion, and Quantity
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Science Is a Human Endeavor
- Technological advances have influenced the progress of science, and science has influenced advances in technology.
- Science and engineering are influenced by society, and society is influenced by science and engineering.

DOK Ceiling
3

Item Format
Selected Response
Constructed Response
Technology Enhanced

Content Limits/Assessment Boundaries

- Tasks should avoid Hardy-Weinberg calculations and dihybrid crosses.
- Tasks should not require students to calculate the probability of polygenic traits.
- Tasks should include support or context for any mode of inheritance beyond complete dominance.

Possible Evidence

- Students organize the given data by the frequency, distribution, and variation of expressed traits in the population. Students may use Punnett squares or pedigrees as models for this standard.
- Students perform and use appropriate statistical analyses of data, including probability measures, to determine the relationship between a trait's occurrence within a population and environmental factors.
- Students analyze and interpret data to explain the distribution of expressed traits, including the following:
  - Recognition and use of patterns in the statistical analysis to predict changes in trait distribution within a population if environmental variables change
  - Description of the expression of a chosen trait and its variations as causative or correlational to some environmental factor based on reliable evidence

Sample Stems

It has been observed that the heights of Wisconsin Fast Plants vary within a population. Fast Plants are a specially bred type of *Brassica rapa* plant which grow very quickly, reaching maturity in 5 weeks instead of 6 months. They reproduce sexually. A student orders Fast Plant seeds to perform a science investigation. The student grows 24 plants, and measures their heights 14 days after planting. The information is summarized in Table 1.

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Stimulus Materials

Graphic organizers, diagrams, graphs, data tables, drawings

Grades 9-12 LIFE SCIENCE

1. Examining which property of the data set allows identification of individuals who are homozygous for recessive height traits? 2. A student claims that meiosis can result in Fast Plants with the rare gene combination of two copies of the *EIN* gene. Identify the plant with which height in the table provides evidence supporting this claim. 3. Find the percent of plants in the student's experiment that are homozygous for *EIN* or *ROS*. Round to the nearest percent. 4. The student crosses plant A, which has a height of 14 cm, with plant B, which has a height of 15 cm. Most of the offspring are normal height and the others are short. The student claims that crossing plant A and plant C, which has a height of 6 cm, can only produce offspring with normal or short phenotypes. Using R as dominant and r as recessive, complete the sentence below. Plant A must have the genotype (RR / Rr / rr) and plant C must have the genotype (RR / Rr / rr). During reproduction of Plant A and Plant C, the process of (natural selection / environmentally-induced mutation / genetic recombination) can result in offspring with normal or short phenotypes. 5. The student's experiment was designed to isolate causes of plant height. In order to produce this outcome, the plants had to be (genetically identical / identical in phenotype / raised under identical conditions), so that the role of (genetics / mutations / the environment) in causing variations in plant growth would be minimized. 6. A group of Fast Plants with the same mix of height genes is grown on a plot of land with abundant soil nutrients, water, and light. The plot of land is exposed to a bird species that preys on tall plants. **Part A:** Based only on this description of the environment, describe what the survival rate of plants in the first generation would most likely be. **Part B:** Explain why plants with a trait that is detrimental in this environment would continue to appear in offspring of surviving plants. **Part C:** Explain how the incidence of the detrimental trait would change over time.	

Grades 9-12 LIFE SCIENCE

Life Sciences		9-12.LS4.A.1
Core Idea Component MLS	**Biological Evolution; Unity and Diversity** **Evidence of Common Ancestry and Diversity** Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.	

Expectation Unwrapped

[Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include, but are not limited to, similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development. Communicate could include, but is not limited to, written report, and oral discussion.]

SCIENCE AND ENGINEERING PRACTICES

Obtaining, Evaluating, and Communicating Information

- Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted.
- If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.

DISCIPLINARY CORE IDEAS

Evidence of Common Ancestry and Diversity

- Genetic information, like the fossil record, provides evidence of evolution.
- DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms.
- Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.

CROSSCUTTING CONCEPTS

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

DOK Ceiling

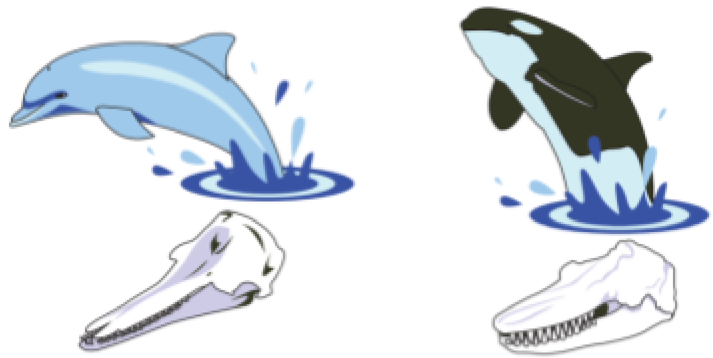
3

Item Format

Selected Response
Constructed Response
Technology Enhanced

Grades 9-12 LIFE SCIENCE

Scientific Knowledge Assumes an Order and Consistency in Natural Systems ● Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and that they will continue to do so in the future.	
Content Limits/Assessment Boundaries ● Tasks should avoid an analysis of phylogenetic trees as a form of empirical evidence. ● Tasks should not require correct citation of information.	**Stimulus Materials** Graphic organizers, diagrams, graphs, data tables, drawings
Possible Evidence ● Students use at least one format (e.g., oral, graphical, textual, mathematical), to communicate scientific information including that common ancestry and biological evolution are supported by multiple lines of empirical evidence. Students cite the origin of the information as appropriate. ● Students identify and communicate evidence for common ancestry and biological evolution, including the following: ○ Information derived from DNA sequences, which vary among species but have many similarities between species ○ Similarities of the patterns of amino acid sequences, even when DNA sequences are slightly different, including the fact that multiple patterns of DNA sequences can code for the same amino acid ○ Patterns in the fossil record (e.g., presence, location, and inferences possible in lines of evolutionary descent for multiple specimens) ○ The pattern of anatomical and embryological similarities ● Students identify and communicate connections between each line of evidence and the claim of common ancestry and biological evolution. ● Students communicate that together, the patterns observed at multiple spatial and temporal scales (e.g., DNA sequences, embryological development, fossil records) provide evidence for causal relationships relating to biological evolution and common ancestry.	
Sample Stems Whales are aquatic mammals. A student studies the odontocetes, a grouping of whales which includes the bottlenose dolphins and killer whales. Unlike other whales, odontocetes have hard teeth. The student compares the body structures of these two species: **Figure 1. Body Structures**	

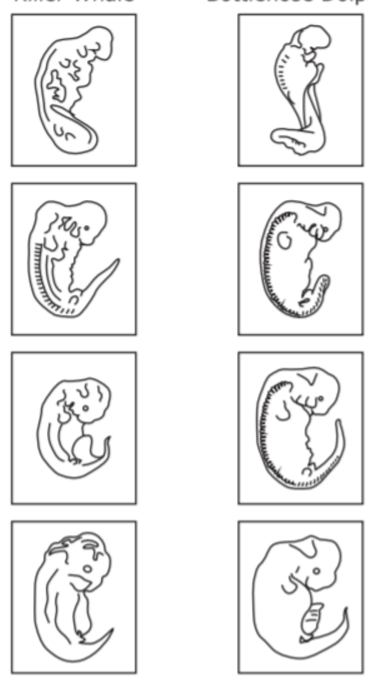


Bottlenose Dolphin   Killer Whale

A comparison of embryonic development in the species shows that both start to develop hind legs early in development, but then lose these structures before birth:

Figure 2. Embryonic Development

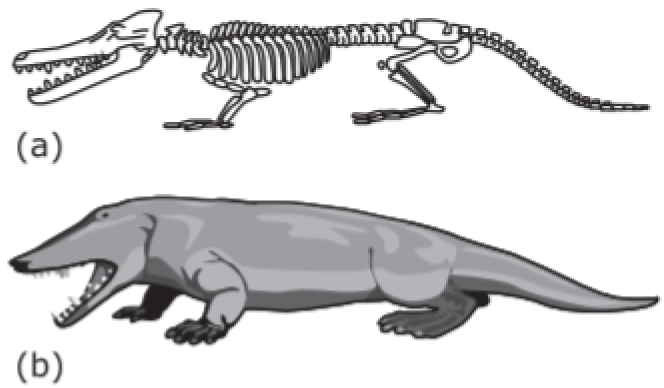
Killer Whale   Bottlenose Dolphin



Grades 9-12 LIFE SCIENCE

The student reads about the history of whales. The literature suggests that whales descend from land mammals which adapted gradually to an aquatic environment. Fossils of one very early whale species, *Ambulocetus natans,* show legs with hooves. The animal is thought to have spent much of its time swimming in water, while retaining its ability to walk on land.

Figure 3. Evolutionary Ancestor



Ambulocetus Natans

7. Skeletal reconstruction (Thewissen, 2002) and (b) Life restoration (Thewisssen and Williams, 2002)

Further evidence for this history of whales comes from genetic comparisons. Comparison of DNA between the hippopotamus and the humpback whale reveals, for example, the following homologous sequences: ATAGGGAATT (hippopotamus) and ATAGGGACTT (humpback whale).

1. Compare the skeletons shown in Figure 3 and Figure 1. The skeleton in Figure 3 is from a species that appeared earlier on the evolutionary time scale. Based on these Figures, what can be concluded about the teeth in these species?
2. In addition to anatomical evidence, studying patterns in DNA sequence provides what is considered good evidence for common ancestry among hippopotami and humpback whales. What is the percent similarity between the DNA sequence of these two species? Round your answer to the nearest percentage point.
3. A student is constructing an explanation of how the ancestry of the hippopotamus and the humpback whale evolved to become different species. Order the events below into an explanation.
   - New species begin to form
   - Distinct sets of heritable adaptations accumulate
   - Natural selection acts in different patterns on existing genetic material
   - Different resource and threat patterns in distinct environments act on sub-populations.

   Explanation: Despite high genetic uniformity, genetic variation exists. [Continue with the statements above in the correct order.]

Life Sciences		9-12.LS4.A.2
Core Idea	Biological Evolution; Unity and Diversity	
Component	Evidence of Common Ancestry and Diversity	
MLS	Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.	

Expectation Unwrapped	DOK Ceiling 3
[Clarification Statement: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.] **SCIENCE AND ENGINEERING PRACTICES** **Obtaining, Evaluating, and Communicating Information** ● Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** ● A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. ● If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. **DISCIPLINARY CORE IDEAS** **Evidence of Common Ancestry and Diversity** ● Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. **CROSSCUTTING CONCEPTS** **Patterns** ● Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. Refer to Engineering, Technology, and Application of Science ETS.1.A.1.	**Item Format** Selected Response Constructed Response Technology Enhanced

Grades 9-12 LIFE SCIENCE

Content Limits/Assessment Boundaries	Stimulus Materials
• Tasks should include embryological pictures of organisms that are familiar to students (e.g., fish, turtle, pig, chicken). • Tasks should be limited to easily identifiable anatomical structures (e.g., head, appendages, tail). • Tasks should avoid cell differentiation (e.g., germ layers).	Graphic organizers, diagrams, graphs, data tables, drawings
Possible Evidence	

• Students analyze pictorial data. In their analysis, students
  ○ compare patterns of similarities across multiple species,
  o describe common physical characteristics, and
  o compare and contrast embryological features to fully formed anatomy of organisms.	

Sample Stems	
[Coming soon!]	

Grades 9-12 LIFE SCIENCE

Life Sciences		9-12.LS4.B.1
Core Idea **Component** **MLS**	**Biological Evolution; Unity and Diversity** **Natural Selection** Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.	

Expectation Unwrapped

[Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.]

SCIENCE AND ENGINEERING PRACTICES

Constructing Explanations and Designing Solutions

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

DISCIPLINARY CORE IDEAS

Natural Selection

- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals.

Adaptation

- Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.

CROSSCUTTING CONCEPTS

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

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Item Format

Selected Response
Constructed Response
Technology Enhanced

Grades 9-12 LIFE SCIENCE

Content Limits/Assessment Boundaries

- Tasks should avoid other mechanisms of evolution (e.g., genetic drive, gene flow through migration, co-evolution).
- Tasks should not require students to differentiate between credible and non-credible sources.

Possible Evidence

- Students construct an explanation that includes a description that evolution is caused primarily by one or more of the four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.
- Students identify and describe evidence to construct their explanation, including that
  - as a species grows in number, competition for limited resources can arise.
  - individuals in a species have genetic variation (through mutations and sexual reproduction) that is passed on to their offspring.
  - individuals can have specific traits that give them a competitive advantage relative to other individuals in the species.
- Students use a variety of valid and reliable sources for evidence (e.g., data from investigations, theories, simulations, peer review).
- Students use reasoning to connect the evidence, along with the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, to construct the explanation. Students describe the following chain of reasoning for their explanation:
  - Genetic variation can lead to variation of expressed traits in individuals in a population.
  - Individuals with traits that give competitive advantages can survive and reproduce at higher rates than individuals without the traits because of the competition for limited resources.
  - Individuals that survive and reproduce at a higher rate will provide their specific genetic variations to a greater proportion of individuals in the next generation.
  - Over many generations, groups of individuals with particular traits that enable them to survive and reproduce in distinct environments using distinct resources can evolve into a different species.
- Students use the evidence to describe the following in their explanation:
  - The difference between natural selection and biological evolution (i.e., natural selection is a process, and biological evolution can result from that process)
  - The cause and effect relationship between genetic variation, the selection of traits that provide comparative advantages, and the evolution of populations that all express the trait

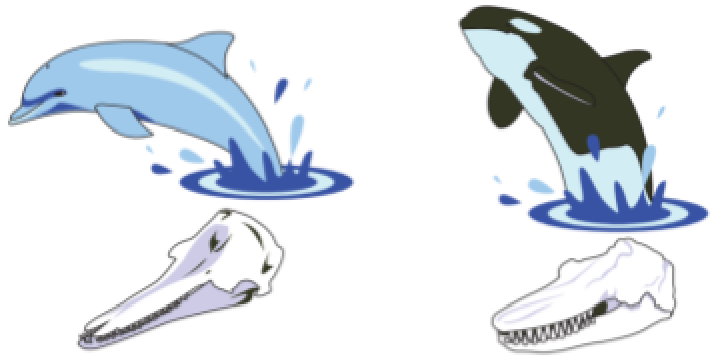
Sample Stems

Whales are aquatic mammals. A student studies the odontocetes, a grouping of whales which includes the bottlenose dolphins and killer whales. Unlike other whales, odontocetes have hard teeth. The student compares the body structures of these two species:

Figure 1. Body Structures

Stimulus Materials

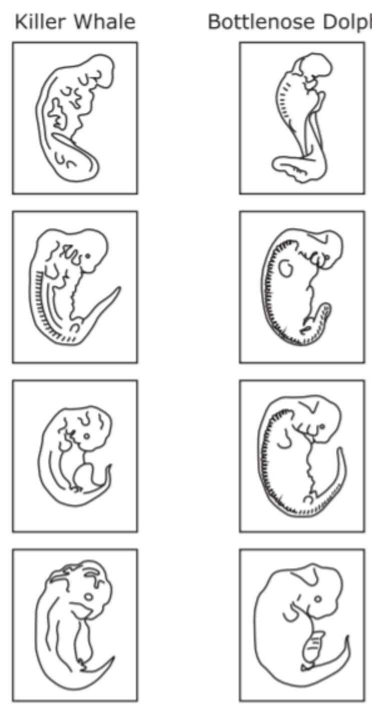
Graphic organizers, diagrams, graphs, data tables, drawings



Bottlenose Dolphin Killer Whale

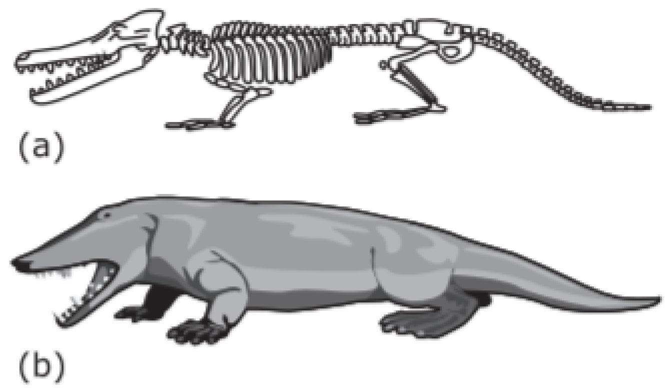
A comparison of embryonic development in the species shows that both start to develop hind legs early in development, but then lose these structures before birth:

Figure 2. Embryonic Development



The student reads about the history of whales. The literature suggests that whales descend from land mammals which adapted gradually to an aquatic environment. Fossils of one very early whale species, *Ambulocetus natans,* show legs with hooves. The animal is thought to have spent much of its time swimming in water, while retaining its ability to walk on land.

Figure 3. Evolutionary Ancestor



Ambulocetus Natans

4. Skeletal reconstruction (Thewissen, 2002) and (b) Life restoration (Thewisssen and Williams, 2002)

Further evidence for this history of whales comes from genetic comparisons. Comparison of DNA between the hippopotamus and the humpback whale reveals, for example, the following homologous sequences: ATAGGGAATT (hippopotamus) and ATAGGGACTT (humpback whale).

1. The student synthesizes information to make a presentation about the evolutionary history of the odontocetes. The student's presentation will include diagrams drawing links between different organisms. Describe the type of diagrams the student would include.
2. A student is using the graphic and textual evidence presented to construct an explanation of how *Ambulocetus natans* evolved over time. The student explains that in the state shown in the diagram, the species was exposed to (one / one land-based and one water-based), set of selection pressures, with (the land environment / the aquatic environment / the amphibious life cycle) ultimately providing the greatest survival opportunities. In response, the species over time (became more adapted to aquatic living / increased in number on land and water / learned aquatic behaviors which became heritable).

Grades 9-12 LIFE SCIENCE

Life Sciences		9-12.LS4.B.2
Core Idea	**Biological Evolution; Unity and Diversity**	
Component	**Natural Selection**	
MLS	Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.	

Expectation Unwrapped

[Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.]

SCIENCE AND ENGINEERING PRACTICES

Analyzing and Interpreting Data

- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.

DISCIPLINARY CORE IDEAS

Natural Selection

- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals.
- The traits that positively affect survival are more likely to be reproduced and thus are more common in the population.

Adaptation

- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.
- Adaptation also means that the distribution of traits in a population can change when conditions change.

CROSSCUTTING CONCEPTS

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

DOK Ceiling

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Item Format

Selected Response
Constructed Response
Technology Enhanced

Grades 9-12 LIFE SCIENCE

<table>
<tr><td>

<u>Content Limits/Assessment Boundaries</u>

- Tasks should be limited to basic statistical and graphical analyses.
- Tasks should avoid allele frequency calculations. Students should be given all needed allele frequencies.

</td><td rowspan="3">

<u>Stimulus Materials</u>

Graphic organizers, diagrams, graphs, data tables, drawings

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<tr><td>

<u>Possible Evidence</u>

- Students organize data (e.g., using tables, graphs, charts) by the distribution of genetic traits over time.
- Students describe what each dataset represents.
- Students perform and use appropriate statistical analyses of data, including probability measures, to determine patterns of change in numerical distribution of traits over various time and population scales.
- Students use the data analyses as evidence to support explanations about the following:
    - Positive or negative effects on survival and reproduction of individuals as relating to their expression of a variable trait in a population
    - Natural selection as the cause of increases and decreases in heritable traits over time in a population, but only if it affects reproductive success
    - The changes in distribution of adaptations of anatomical, behavioral, and physiological traits in a population

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<u>Sample Stems</u>

[Coming soon!]

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</table>

Life Sciences		9-12.LS4.C.1
Core Idea	**Biological Evolution; Unity and Diversity**	
Component	**Adaptation**	
MLS	Construct an explanation based on evidence for how natural selection leads to adaptation of populations.	

Expectation Unwrapped

[Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]

SCIENCE AND ENGINEERING PRACTICES

Constructing Explanations and Designing Solutions

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review), and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

DISCIPLINARY CORE IDEAS

Adaptation

- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.

CROSSCUTTING CONCEPTS

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects.

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and will continue to do so in the future.

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Item Format
Selected Response
Constructed Response
Technology Enhanced

<table>
<tr><td>

Content Limits/Assessment Boundaries

- Tasks should provide students with data to interpret.
- Tasks should not require students to distinguish between credible and non-credible sources.
- Tasks should not require students to calculate gene frequency.

</td><td rowspan="3">

Stimulus Materials

Graphic organizers, diagrams, graphs, data tables, drawings

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<tr><td>

Possible Evidence

- Students construct an explanation that identifies the cause and effect relationship between natural selection and adaptation.
- Students identify and describe the evidence to construct their explanation, including the following:
  - Changes in a population when some feature of the environment changes
  - Relative survival rates of organisms with different traits in a specific environment
  - The fact that individual organisms in a species have genetic variation (through mutations and sexual reproduction) that is passed on to their offspring
  - The fact that individual organisms can have specific traits that give them a competitive advantage relative to other individual organisms in the species
- Students use a variety of valid and reliable sources for the evidence (e.g., theories, simulations, peer review, students' own investigations).
- Students use reasoning to synthesize the valid and reliable evidence to distinguish between cause and correlation to construct the explanation about how natural selection provides a mechanism for species to adapt to changes in their environment, including the following elements:
  - Biotic and abiotic differences in ecosystems contribute to changes in gene frequency over time through natural selection.
  - Increasing gene frequency in a population results in an increasing fraction of the population in each successive generation that carries a particular gene and expresses a particular trait.
  - Over time, this process leads to a population that is adapted to a particular environment through the widespread expression of a trait that confers a competitive advantage in that environment.

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Sample Stems

Two Species or One?

Scientists are helping a group of people on Norfolk Island in the South Pacific Ocean protect a population of birds currently known as Pacific Robins. Scientists collected data on genetic and physical characteristics to decide if the population:

A. should continue to be classified as Pacific Robins
B. is more closely related to other nearby robin species (Scarlet Robins or Red-Capped Robins), or
C. is its own species of Norfolk Island Robins.

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The birds on Norfolk Island are currently declining in number because of predation from rats, and because humans are clearing the forest habitats where they prefer to live. If the scientists decide this population of birds is its own species, then the group will take steps to protect them. However, if the scientists decide they are more closely related to other bird species, the Norfolk Islands robins will not be protected.

The scientists compared four populations of robins with respect to their genetic similarity and physical characteristics. Scientists agree that the following are separate species:

- Scarlet Robins
- Red-Capped Robins
- Pacific Robins

The question is whether the Norfolk Island Robins are a different species from the other three, based on both genetic and physical data.

Data on Genetic Similarity

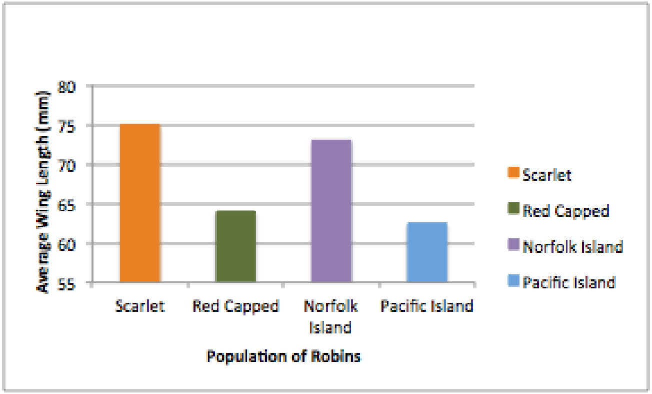
The scientists decided to compare genetic similarities of Norfolk Island (NI) robins (for the alleles of ND2 gene) to each of these populations of robins.

Red-capped Robin (different species): 98.2% similar to the NI robins

Pacific Robins (population we want to know about): 96.7% similar to the NI robins

Scarlet Robins (different species): 88.7% similar to the NI robins

Figure 1. Average Wing Length of the Different Populations of Robins



1. Using the basis of these data, which group of robins most likely shares a <u>most recent</u> common ancestry with the Norfolk Island robins? 2. **Part A:** Which data beswt support your claim? **Part B:** Why are these data important to scientists in determining common ancestry? 3. **Part A:** What patterns in the data are relevant to deciding whether the species are the same or different, but do **not** support your claims? **Part B:** Why are these sources of data in general important to scientists in determining common ancestry? 4. **Part A:** If you were a scientist, what would you conclude: Should the Norfolk Island robins be considered a unique species? **Part B:** What evidence supports your conclusion in Part A? **Part C:** What is your reasoning? [In other words, why is that good evidence to support your conclusion?] 5. What is one additional piece of evidence that would help convince you that the Norfolk Island robins are the same or different from other island bird species? Describe what the evidence would have to show to support your claim. 6. The Pacific Robin and Red-Capped Robin do not interbreed because they cannot reach each other in flight (their short wings are not useful for flying long distances). Additionally, over time their habitats may start to vary. The Pacific Robin's habitat will likely be the same because people decided to protect the environment and limit any future development. The Red-Capped Robin's habitat is at risk of being destroyed by human activity (such as building hotels for tourists). **Part A:** Over multiple generations, what could happen to these two populations? (Circle two plausible answers) a. The two populations' wing lengths would stay about as similar to one another as they are today. b. The two populations' wing lengths would become more different from one another as the Red-Capped robins adapted to different conditions. c. The Red-Capped Robin population would go extinct. **Part B:** Explain your reasoning for each answer you select.	

Grades 9-12 LIFE SCIENCE

<table>
<tr><th colspan="2">Life Sciences</th><th>9-12.LS4.C.2</th></tr>
<tr><td>Core Idea
Component
MLS</td><td colspan="2">Biological Evolution; Unity and Diversity
Adaptation
Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.</td></tr>
<tr><td colspan="2"><u>Expectation Unwrapped</u>

[Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, droughts, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]

<u>SCIENCE AND ENGINEERING PRACTICES</u>
Engaging in Argument from Evidence
● Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.

<u>DISCIPLINARY CORE IDEAS</u>
Adaptation
● Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species.
● Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.

<u>CROSSCUTTING CONCEPTS</u>
Cause and Effect
● Empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects.</td><td><u>DOK Ceiling</u>
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<u>Item Format</u>
Selected Response
Constructed Response
Technology Enhanced</td></tr>
<tr><td colspan="2"><u>Content Limits/Assessment Boundaries</u>

● Tasks should provide students with a claim and initial evidence for evaluation.
● Tasks should not require students to use group behavior as a source of support.</td><td><u>Stimulus Materials</u>

Graphic organizers, diagrams, graphs, data tables, drawings</td></tr>
</table>

Possible Evidence

- Students identify the given claims, which include the idea that changes in environmental conditions may result in
    - increases in the number of individual organisms of some species;
    - the emergence of new species over time, and
    - the extinction of other species.
- Students identify and describe additional evidence (in the form of data, information, models, or other appropriate forms) that was not provided but is relevant to the claims and to evaluating the given evidence, including the following:
    - Data indicating the change over time in
        - the number of individual organisms in each species,
        - the number of species in an environment, and
        - the environmental conditions.
    - Environmental factors that can determine the ability of individual organisms in a species to survive and reproduce
- Students use their additional evidence to assess the validity, reliability, strengths, and weaknesses of the given evidence, along with its ability to support logical and reasonable arguments about the outcomes of group behavior.
- Students assess the ability of the given evidence to be used to determine causal or correlational effects between environmental changes, the changes in the number of individuals in each species, the number of species in an environment, and/or the emergence or extinction of species
- Students evaluate the degree to which the given empirical evidence can be used to construct logical arguments that identify causal links between environmental changes and changes in the number of individual organisms or species based on environmental factors that can determine the ability of individual organisms in a species to survive and reproduce.

Sample Stems

Chaetognaths, or “arrow worms,” are a phylum of predatory marine worms. A research station compares two closely related chaetognaths, *Sagitta elegans* and *Sagitta setosa,* which live in the same geographical area but at different water depths.

Sagitta setosa lives closer to the surface and has access to a higher density of prey organisms, but its prey organisms have small sizes. It cannot eat prey organisms over a certain size because *Sagitta* worms swallow their prey whole, adn the mount of *Sagitta setosa* is, like its body size, small.

Sagitta elegans lives in deeper water and consumes fewer organisms, but its prey are larger in size. Each species is found in the habitat of the other, but cluster mainly at their own depths.

In 24 hours, *Sagitta elegans* consumes an average of 439 prey, while *Sagitta setosa* consumes an average of 1,213 prey. Information about these two species is summarized in Table 1.

Table 1. Comparison of Sagitta Species

Organism	Depth of primary habitat (meters)	Medium body length (mm)
Sagitta elegans	20+	24
Sagitta setosa	0-20	7

1. Explain the factor that is most likely keeping *Sagitta elegans* from further increasing in median body length.
2. Both species of worm are found at all depths, though the species have preferred depth ranges. Use the data to evaluate the merits of the argument that chaetognatha populations would change if the water from various depths mixed.

   High winds result in temperature mixing of water. Because Chaetognath (parasite / prey / predator) populations are (sensitive to temperature / tolerant to temperature changes), the Chaetognaths (do no maintain / maintain / thrive and increase) their current population sizes.
3. A researcher proposes a model in which *Sagitta setosa* populations fall while their body lengths increase, gradually leading to formation of a new species. Order the evidence provided for past changes in chaetognaths to complete this model.
   - A new species emerges.
   - Prey populations increase in body size, but decrease in number.
   - Genes for longer body lengths spread through successive worm generations.
   - Individuals with larger mouths show an increased probability of survival.

Grades 9-12 LIFE SCIENCE

Life Sciences		9-12.LS4.C.3
Core Idea Component MLS	**Biological Evolution; Unity and Diversity** **Adaptation** Create or revise a model to test a solution to mitigate adverse impacts of human activity on biodiversity.	

Expectation Unwrapped

[Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species or to genetic variation of organisms for multiple species.]

SCIENCE AND ENGINEERING PRACTICES
Mathematics and Computational Thinking
- Create or revise a simulation of a phenomenon, designed device, process, or system.

DISCIPLINARY CORE IDEAS
Adaptation
- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species.

Biodiversity and Humans
- Humans depend on the living world for the resources and other benefits provided by biodiversity.
- But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth.
- Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

Developing Possible Solutions
- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.
- Both physical models and computers can be used in various ways to aid in the engineering design process.
- Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical and in making a persuasive presentation to a client about how a given design will meet his or her needs.

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Item Format
Selected Response
Constructed Response
Technology Enhanced

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<u>CROSSCUTTING CONCEPTS</u>
Cause and Effect
Empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects.
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<u>Content Limits/Assessment Boundaries</u>

Tasks should provide students with all necessary background information for a given scenario. Students should not require students to develop their own scenarios.
Tasks do not have address both the creation and revision of the given model.

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<u>Stimulus Materials</u>
Graphic organizers, diagrams, graphs, data tables, drawings
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<u>Possible Evidence</u>

Students create or revise a model that

explains effects of human activity (e.g., overpopulation, overexploitation, adverse habitat alterations, pollution, invasive species, changes in climate) on a threatened or endangered species or to the genetic variation within a species and
provides quantitative information about the effect of the solutions on threatened or endangered species.

Students describe or identify the components of the model including human activity (e.g., overpopulation, overexploitation, adverse habitat alterations, pollution, invasive species, changes in climate) and the factors that affect biodiversity.
Students describe the variables that can be changed within the model to evaluate the proposed solutions, trade-offs, or other decisions.
Students show an understanding of the reliance of ecosystem function and productivity on biodiversity, and that take into account the limitations (constraints) of cost, safety, and reliability as well as cultural, and environmental impacts.
Students use or identify possible negative consequences of solutions that would outweigh their benefits.
Students analyze the modeled results to determine whether the model provides sufficient information to evaluate the solution.
Students identify the model’s limitations.
Students interpret the modeled results, and predict the effects of the specific design solutions on biodiversity based on the interpretation.
Students revise the model as needed to provide sufficient information to evaluate the solution.

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<u>Sample Stems</u>

A researcher investigating cattle in the Blue Mountains of Oregon observes the cattle drinking water from a local stream. The activity of the cattle muddies the clear water of the stream. After the cattle depart, the researcher finds that they have trampled and destroyed several fish eggs, which turn out to be from trout. and salmon species listed as “Threatened” under the Endangered Species Act. Salmon consume tiny animals, which in turn consume tiny producer organisms. The producers depend on sunlight passing into the water so that they can perform photosynthesis.
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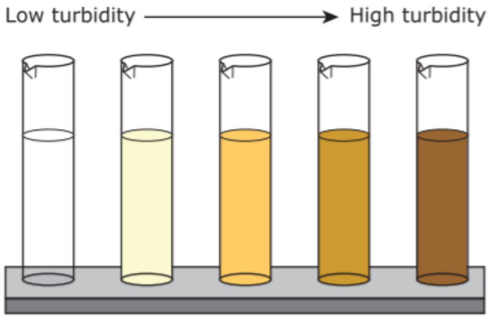
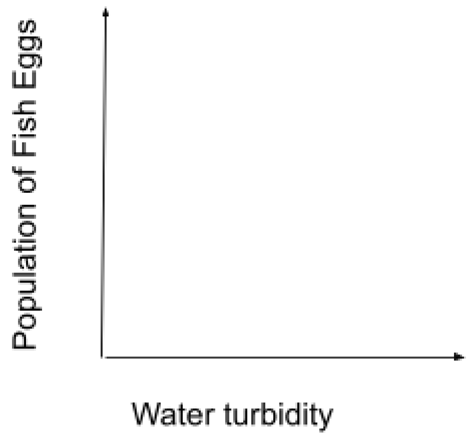
Grades 9-12 LIFE SCIENCE

Figure 1. Water Turbidity



1. Turbidity is a measure of the cloudiness of the water due to the presence of tiny particles in the water. A researcher is working on a simulation of the impact of reducing water turbidity on threatened salmon populations. Based on the food chain information, describe the data line the simulation should most likely generate on the model to the right.



2. A researcher is working on a simulation to test the impact of a program of collecting and incubating threatened fish eggs and releasing them as young fish back into the environment. The simulation will be created to investigate whether the program successfully reduces the impact of cattle. It will also investigate the economic impacts of the program.

   Part A: To perform its functions, the simulation should be created to investigate whether the program successfully reduced the impact of cattle ranching by predicting
   a. whether cattle or fish are of greater economic value
   b. the lowest cost way to implement program procedures
   c. the cost per fish of implementing this program relative to others
   d. the proportion of fish produced under this program that are eaten by predators
   e. the proportion of eggs hatched under this program that are expected to survive

   Part B: To perform its functions, the simulation should be created to investigate whether the program is economical by predicting
   a. whether cattle or fish are of greater economic value
   b. the lowest cost way to implement program procedures
   c. the cost per fish of implementing this program relative to others
   d. the proportion of fish produced under this program that are eaten by predators
   e. the proportion of eggs hatched under this program that are expected to survive